ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION

FOR

THE YEAR 1877.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1878.

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FORTY-FIFTH CONGRESS—SECOND SESSION.

IN THE SENATE OF THE UNITED STATES.

APRIL 25, 1878.

The following resolution was agreed to by the Senate March 6, 1878, and concurred in by the House of Representatives April 24, 1878:

Resolved by the Senate (the House of Representatives concurring), That ten thousand five hundred copies of the Report of the Smithsonian Institution for the year 1877 be printed; one thousand copies of which shall be for the use of the Senate, three thousand copies of which shall be for the use of the House of Representatives, and six thousand five hundred copies for the use of the Smithsonian Institution: *Provided*, That the aggregate number of pages shall not exceed five hundred, and that there be no illustrations except those furnished by the Smithsonian Institution.

April 25, 1878.

Attest:

GEO. C. GORHAM,
Secretary.
By W. J. McDONALD,
Chief Clerk.

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LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The annual report of the Board of Regents of that Institution for the year 1877.

FEBRUARY 15, 1878.—Ordered to be printed.

SMITHSONIAN INSTITUTION,
Washington, February 6, 1878.

SIR: In behalf of the Board of Regents, I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1877.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. W. A. WHEELER,
President of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR 1877.

CONTENTS.

1. Annual report of the Secretary, giving an account of the operations and condition of the establishment for the year 1877, with the statistics of collections, exchanges, &c.

2. Report of the Executive Committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, the receipts and expenditures for the year 1877, and the estimates for 1878.

3. Proceedings of the Board of Regents for the session of January, 1878.

4. General appendix, consisting principally of translations from foreign journals or works not generally accessible, but of interest to the collaborators and correspondents of the Institution, teachers, and others interested in the promotion of knowledge.

THE SMITHSONIAN INSTITUTION.

RUTHERFORD B. HAYES, President of the United States, *ex officio* Presiding Officer.
MORRISON R. WAITE, Chief Justice of the United States, Chancellor of the Institution (President of the Board of Regents).
JOSEPH HENRY, Secretary (Director of the Institution).
SPENCER F. BAIRD, Assistant Secretary (Superintendent of the National Museum.)
WILLIAM J. RHEES, Chief Clerk.

REGENTS OF THE INSTITUTION.

MORRISON R. WAITE, Chief Justice of the United States, *President.*
WILLIAM. A. WHEELER, Vice-President of the United States.
HANNIBAL HAMLIN, member of the Senate of the United States.
AARON A. SARGENT, member of the Senate of the United States.
ROBERT E. WITHERS, member of the Senate of the United States.
HIESTER CLYMER, member of the House of Representatives.
ALEXANDER H. STEPHENS, member of the House of Representatives.
JAMES A. GARFIELD, member of the House of Representatives.
JOHN MACLEAN, citizen of New Jersey.
PETER PARKER, citizen of Washington, D. C.
ASA GRAY, citizen of Massachusetts.
HENRY COPPEE, citizen of Pennsylvania.
GEORGE BANCROFT, citizen of Washington, D. C.
NOAH PORTER, citizen of Connecticut.

EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS.

PETER PARKER. JOHN MACLEAN. GEORGE BANCROFT.

MEMBERS EX OFFICIO OF THE INSTITUTION.

RUTHERFORD B. HAYES, President of the United States.
WILLIAM A. WHEELER, Vice-President of the United States.
MORRISON R. WAITE, Chief Justice of the United States.
WILLIAM M. EVARTS, Secretary of State.
JOHN SHERMAN, Secretary of the Treasury.
GEORGE W. McCRARY, Secretary of War.
RICHARD W. THOMPSON, Secretary of the Navy.
DAVID M. KEY, Postmaster-General.
CARL SCHURZ, Secretary of the Interior.
CHARLES DEVENS, Attorney-General.
ELLIS SPEAR, Commissioner of Patents.

OFFICERS AND ASSISTANTS OF THE SMITHSONIAN INSTITUTION AND NATIONAL MUSEUM, JANUARY, 1878.

JOSEPH HENRY,
Secretary, Director of the Institution.
SPENCER F. BAIRD,
Assistant Secretary, Superintendent of National Museum.
WILLIAM J. RHEES,
Chief Clerk.
DANIEL LEECH,
Clerk, Correspondence.
CLARENCE B. YOUNG,
Clerk, Accounts.
HERMANN DIEBITSCH,
Clerk, Foreign Exchanges.
JANE A. TURNER,
Clerk, Library.
MAGGIE E. GRIFFIN,
Clerk, Distribution of Publications.
SOLOMON G. BROWN,
Clerk, Transportation.

G. BROWN GOODE,
Assistant, Zoology.
F. M. ENDLICH,
Assistant, Mineralogy.
ROBT. RIDGWAY,
Assistant, Ornithology.
TARLETON H. BEAN,
Assistant, Ichthyology.
CHAS. RAU,
Assistant, Archæology.
EDWARD FOREMAN,
Assistant, Ethnology.
F. H. CUSHING,
Assistant, Ethnology

JOSEPH PALMER,
Taxidermist.
T. W. SMILLIE,
Photographer.
JOSEPH HERRON,
Janitor.

REPORT OF JOSEPH HENRY, SECRETARY, FOR THE YEAR 1877.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor herewith to present to you a report of the operations and condition of the Institution, intrusted to your care by the Government of the United States, for the year 1877.

INTRODUCTION.

Nothing of special importance has occurred during the past year to vary the conditions and operations of the establishment, while from the following report I think it will be evident that it has continued faithfully to discharge the duties assigned it by the will of the founder, as well as to carry out the directions prescribed by Congress in the act of its organization.

In the last report a full account was given of the operations of the Institution in connection with the Centennial Exhibition, and in relation to this the Board of Regents addressed a memorial to Congress, asking for an appropriation of $250,000 for the erection of a new building, principally to accommodate the articles presented by foreign governments to the National Museum under the care of the Institution. A bill in favor of this petition was presented to the Senate by the Hon. Mr. Morrill, of Vermont, which passed without opposition. It failed, however, to pass the House of Representatives, although a majority of the members approved of it, because it could not be brought before the House without a two-thirds vote in favor of its consideration. The same bill will again be presented, and the hope is confidently entertained that it will receive the approbation of Congress. In anticipation of this result a plan of the building has been prepared under the direction of General Meigs.

In the two preceding reports I have called the attention of the Board of Regents to the propriety of a final separation of the Institution from the National Museum, and nothing has occurred during the past year to change my opinion on this point. Although I do not urge this for immediate action, yet I think it should be kept in view, and the proposition at a favorable time presented to Congress. My reason for advocating this proposition is that Smithson gave his own name to the establishment which he founded, thereby indicating that he intended it as a monument to his memory, and in strict regard to this feature of his will his bequest should be administered separately from all other funds and the results achieved by it, accredited to his name alone. The Institution,

therefore, should not be merged in any establishment of the government, but should stand isolated, free to the unobstructed observation of the whole world, keeping in per tual remembrance the will of its founder.

The functions of the Institution and the Museum are entirely different; those of the Institution being—first, to enlarge the bounds of human thought by assisting men of science to make original investigations in all branches of knowledge, to publish these at the expense of the Smithson fund, and to present copies of them to all the principal libraries of the world; second, to institute investigations in various branches of science and explorations for the collection of specimens in natural history and ethnology to be distributed to museums and other establishments; third, to diffuse knowledge by carrying on an extended international series of exchanges by which the accounts of all the original researches in science, the educational progress, and the general advance of civilization in the New World are exchanged for similar works of the Old World. To carry out this plan the Institution requires no costly building, but merely accommodations for receiving and distributing its collections.

The Museum, on the other hand, is intended to embrace a collection of specimens of nature and art which shall exhibit the natural resources and industries of the country, or to present at one view the materials essential to the condition of high civilization which exists in the different States of the American Union; to show the various processes of manufacture which have been adopted by us, as well as those used in foreign countries; in short, to form a great educational establishment by means of which the inhabitants of our own country, as well as those of foreign lands who visit our shores, may be informed as to the means which exist in the United States for the enjoyment of human life in the present, and the improvement of these means in the future.

The support of such an establishment must, of necessity, be derived from Congress, and no part of the income of the Smithson fund should be devoted to this purpose, since it is evident from the will of Smithson that he intended his benefaction for the good of mankind, and therefore all expenditures on local objects, or even on those limited to the United States, are not in conformity with the intentions of the donor. A very objectionable result of the present connection of the two establishments is the necessity for the Institution to appeal to Congress annually for an appropriation for the support of the Museum, whereby the Institution is presented to the world as a suppliant for aid, although, for carrying out the legitimate objects of the bequest, no annual appropriation from the public Treasury is necessary.

The whole of the Smithsonian building is now required for the National Museum, and, in case of the separation, a new building should be provided for the accommodation of the Institution; and when the financial condition of the country shall be better, I trust the sense of justice of the people of the United States will induce Congress to restore to the funds

of Smithson at least a part of the $500,000 which have been expended on the building from the income of the Smithson bequest. I know that the present is a very unfavorable time for presenting this proposition to Congress, but I do not despair of its being favorably received hereafter.

Among the minor incidents of the year was the reception of a letter from M. de la Batut, of Belz, France, the half-brother of the nephew of Smithson, to whom he bequeathed his property, and in case of whose death it was to be devoted to founding the Smithsonian Institution. With this letter was a miniature likeness of James Smithson and another of Colonel Dickinson, the half-brother of Smithson, which were offered for sale to the Institution, and were finally purchased for the sum of $100. Accompanying these portraits was what appeared to be the original draft of Smithson's will, slightly differing in one particular from that previously published in the Smithsonian report for 1853, and also a series of notes addressed to Smithson by some of the most distinguished scientists of his day. Among these are those from Oersted, Arago, Biot, Lester, Tennant, Klaproth, and others, which would be highly prized by collectors of autographs, and which serve to show the intimate association of Smithson with the most distinguished cultivators of science at the beginning of the present century.

There are now in the Institution three likenesses of Smithson, one a small full-length picture, which was purchased from his servant, John Fittall, and represents him in the costume of a student at Oxford; another, a small medallion, which was among his effects; and the third is the one above mentioned. As a part of the legacy of Smithson there were received a small library and several large trunks filled with clothing, some articles of apparatus, a silver-plated dinner set, two small cabinets of minerals, and a large collection of papers, including correspondence. All of these, except the library, were destroyed in the fire of 1865. The effects were, however, of little value, except as mementos. The manuscripts consisted principally of private letters and a series of sentences arranged according to the letters of the alphabet, as if they were intended for a philosophical dictionary. The library, which is still preserved, consists of 123 volumes and 88 pamphlets, and is preserved in a separate case in the Regents' room of the Institution.

In the report of the Institution for 1853 I gave a list of the scientific papers of Smithson which were published in the Transactions of the Royal Society of London and in scientific periodicals. Although at the present day there is nothing in these papers of very special interest, since the facts which he communicated have since been merged in the general progress of science, yet it might be well to republish them in a separate volume as an illustration of the character of the founder of the Institution and to mark his connection with the science of his day.

In the report for the year 1876 an account was accidentally omitted of the decease of Fielding B. Meek, an esteemed collaborator of this

Institution, who occupied for upward of twenty years a room in the Smithsonian building and assisted without salary in the operations of the establishment. He was devoted to paleontology, and was one of the principal authorities in the country in the line of fossil shells. At the time of his death he had just completed a large volume on the paleontology of the Upper Missouri, published in connection with Dr. Hayden's surveys. He was obliged on account of his health to spend his winters in Florida, but, delaying his departure too long and unduly exerting himself the day before he intended to leave, he was seized with a hemorrhage, and, after an illness of a few days, died on the 21st December, 1876. He was born in the city of Madison, Ind., December 10, 1817, and had therefore just completed his fifty-ninth year at the time of his death. His grandparents were Irish Presbyterians, who emigrated to this country from the county of Armagh about the year 1768. His father died when he was but three years old, leaving the family in moderate circumstances. He was educated in the public schools of Madison. His attention was early attracted to the fossil shells so abundant in the rocks in the vicinity of his home. Arriving at the age of manhood, he invested the small sum received from his father's estate in mercantile business, but having no taste for that occupation, and neglecting it to pursue his studies, a failure was the consequence. He then devoted himself as a means of livelihood to portrait-painting, continuing his scientific studies, especially in the line of geology. In the year 1848 he was associated with David Dale Owen in the geological survey of Iowa and Minnesota, and in 1852 became an assistant to Professor Hall in the preparation of the paleontology of the State of New York. Under the direction of Professor Hall he explored the Bad Lands of Nebraska, and collected a valuable series of fossils. In 1858 he came to Washington, where he resided continuously to the time of his death, leaving the city for a few months only from time to time while engaged in studying the paleontology of Illinois, Ohio, and California, and later in Florida during the winter on account of his health. During his residence in the Institution he gradually lost his hearing, and could only be communicated with by means of writing. He gradually withdrew from social intercourse, and devoted his life exclusively to the prosecution of science. He was in correspondence with the principal investigators of the world in the line of paleontology, and although scarcely known in this city his name was familiar to the cultivators of geology everywhere. He was a man of singular truthfulness and critical accuracy, and was highly esteemed by the few who had the pleasure of his acquaintance. His death has been widely announced in all the scientific journals of the day, but no relative has appeared to claim his property. As secretary of the Institution with which he had been so long connected, I considered it my duty to assume the office of administrator, and as a year has now elapsed since the time of his decease I am about to make a report of the condition of his estate to the orphans' court of the District of Columbia. The final disposition of his

property, which is partly in lands in Kansas, cannot be determined at present, and if not claimed by heirs may possibly require the action of Congress.

MEETING OF THE ESTABLISHMENT.

The law of Congress organizing the Smithsonian Institution directs that the President and his Cabinet, the Chief Justice, the Commissioner of Patents, and such other persons as they may elect honorary members, may hold stated and special meetings for inspecting the affairs of the Institution, and, in accordance with this provision, a meeting of that body was held on the 5th of May, 1877. There were present the President of the United States, R. B. Hayes; the Secretary of State, W. M. Evarts; the Secretary of the Treasury, John Sherman; the Secretary of War, George W. McCrary; the Secretary of the Interior, Carl Schurz; the Attorney-General, Charles Devens, and the Postmaster-General, D. M. Key.

The Secretary of the Institution, who is also the secretary of this body, gave a full account of the history, operations, and state of the finances of the Institution; and, after listening to it with interested attention, the President, on behalf of the meeting, expressed the opinion that the condition and management of the Institution were entirely satisfactory, and that they had no improvement to suggest. After inspecting the building, the museum, and the system of exchanges, and examining the publications, the meeting adjourned to meet on the 1st Tuesday in May, 1878.

FINANCES.

The condition of the funds is nearly the same as in 1876. The only difference is a diminution in the marketable value of the Virginia bonds which has fallen from $42,000 to $34,562. This decline was occasioned by propositions made in the legislature of the State which were thought to savor of repudiation, but those propositions have not met with favorable consideration, and it is now confidently expected that the bonds will again advance in value.

The following is a statement of the condition of the fund at the beginning of the year 1878:

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States in accordance with the act of Congress of August 10, 1846	$515,169	00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States in accordance with the act of Congress of February 8, 1867	26,210	63
Total bequest of Smithson	541,379	63
Amount deposited in the Treasury of the United States, as authorized by act of Congress of February 8, 1867, derived from savings of income and increase in value of investments	108,620	37

Amount received as the bequest of James Hamilton, of Carlisle, Pa., February 24, 1874	$1,000 00
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold	651,000 00
In addition to the above, there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz: Consolidated bonds, $58,700; deferred certificates, $29,375.07; fractional certificate, $50.13; total, $88,125.20, valued January, 1878	34,562 00
Cash balance in United States Treasury at the beginning of the year 1878 for current expenses	25,083 90
Total Smithson funds January 6, 1878*	$710,645 90

The receipts during the year 1877 were $49,007.62, and the expenditures $44,952.90, leaving a balance of $4,054.72 to be added to the balance on hand at the beginning of 1877.

The interest on the Virginia bonds received during the year was $2,885.76, realized from the sale of coupons amounting to $3,522.

The interest on the Hamilton bequest of $1,000 has been received to the 31st December, 1877. There is now a balance on hand of interest amounting to $96.17, which will be available during the present year in accordance with the terms of the bequest.

BUILDING.

Attention having been specially called to the condition of the public buildings in this city, on account of the destruction by fire of part of the Patent Office, it was deemed advisable to give additional security to the valuable collections deposited in the Smithsonian edifice. The main building, which contains the National Museum, is entirely fire-proof, but the connecting ranges and the two wings are not so. It was therefore highly desirable that the main building should be entirely isolated from the ranges and wings. For this purpose the large windows facing the wings were bricked up, and all the doorways leading from the museum into the ranges either bricked up or fitted with iron instead of wooden doors. The carpenter's and machinist's shops were removed to the main basement and inclosed in brick walls. The storage rooms were made fire-proof by replacing wooden partitions and floors, by those of brick. In the high central tower brick partitions have been constructed on the stairways, to prevent the passage of fire from one story to another.

PUBLICATIONS.

The publications of the Institution are of three classes, viz, the CONTRIBUTIONS TO KNOWLEDGE, the MISCELLANEOUS COLLECTIONS, and

* The date at which the settlement of the accounts for 1877 was made.

the ANNUAL REPORTS. The first consists of memoirs containing positive additions to science resting on original research, and which are generally the result of investigations to which the Institution has, in some way, rendered assistance. The Miscellaneous Collections are composed of works intended to facilitate the study of various branches of natural history, meteorology, &c., and are principally designed to induce individuals to engage in these studies as specialties. The Annual Reports, besides an account of the operations, expenditures, and condition of the Institution, contain translations from works not generally accessible to American students, reports of lectures, extracts from correspondence, &c.

The following are the rules which have been adopted for the distribution of the several publications of the institution:

1st. They are presented to learned societies of the first class which in return give complete series of their publications to the Institution.

2d. To libraries of the first class which give in exchange their catalogues and other publications, or an equivalent from their duplicate volumes.

3d. To colleges of the first class which furnish catalogues of their libraries and of their students, and all other publications relative to their organization and history.

4th. To States and Territories, provided they give in return copies of all documents published under their authority.

5th. To public libraries in this country, containing 15,000 volumes, especially if no other copies are given in the same place; and to smaller libraries where a large district would be otherwise unsupplied.

6th. To institutions devoted exclusively to the promotion of particular branches of knowledge are given such Smithsonian publications as relate to their respective objects.

7th. The Annual Reports are presented to the meteorological observers, to contributors of valuable material to the library or collections, and to persons engaged in special scientific research.

The most important memoir accepted during the year for publication in the Smithsonian Contributions is entitled "Archæological and Ethnological Researches in Central and South America, with a Detailed Account of the Sculptures at Santa Lucia Cosumalwhuapa," by Dr. Habel, of New York. This gentleman, having an ardent desire to make an exploration of the physical geography and anthropology of Central America, relinquished his medical practice in 1862, and commenced a tour of exploration in that region. In the course of seven years which he devoted to these explorations he made collections in natural history and observations in meteorology, topography, geology, and archæology. On arriving at Guatemala he made that city his headquarters, from which four excursions were undertaken.

The first was directed to an unexplored region lying north of Guatemala, reported to be inhabited by the Lacandones, a tribe said never to have been subdued by Europeans. On the route, Dr. Habel heard of

the remains of two cities near Rabinal, one of which, twelve miles from the town, he visited. These ruins occupy the summits of three hills, and some of the edifices are tolerably well preserved. The most conspicuous one was 100 feet long by 30 feet broad. Its floor was elevated four steps above the ground, and the walls left standing were about 6 feet high. It seems to have had four entrances, one on each side. The interior space was 18 feet broad by nearly 90 feet long. All the buildings were constructed of thin slabs of mica-gneiss laid in courses like bricks and united by a granular kind of mortar. The walls had been plastered outside and inside. On the side of the hill were found arrow-heads and spear-points of obsidian and other minerals.

Arriving at Salinas there were found vestiges of the ancient population in a squared-stone pyramid, heaps of broken pottery, &c. A vocabulary of the Egkschi language was collected. After waiting a month for a boat to convey him to his intended destination, he was obliged to relinquish the attempt and return to Guatemala.

The second exploration was to the borders of Mexico, and ancient ruins were visited at Guequetenango, Palyah, and Saycap.

On the third excursion the sculptures of Copan, in Honduras, described by Stephens and others, were visited. Those of Guirigua are of great archæological interest. These are of various sizes and shapes, the tallest being of columnar form about 25 feet high, while others do not exceed 12 feet. All of them have four sculptured sides, the front and rear being the widest. The narrow sides of all the columnar monoliths are covered with hieroglyphics resembling those found in Copan.

The fourth excursion was undertaken to visit a newly discovered series of sculptures at Santa Lucia Cosumalhuapa, the description of which forms the principal part of this memoir. On the way to this place very interesting sculptures were found on the plain near the Hacienda los Tarros, which exhibit fine workmanship and represent human figures in high relief. They are 5 feet 9 inches high, 3 feet 7 inches broad, and 1 foot 8 inches deep, standing on a base 10 inches high.

Before describing the objects found at Santa Lucia the author gives an account of some other expeditions. The first of these was to the Republic of Honduras, but no archæological objects were observed. Vocabularies and valuable information, however, were collected from various native tribes.

A visit was also made to Nicaragua, where a sculptured figure was seen on the corner-stone of a house, and other remains were found in and near the town. A grotesque figure was observed sculptured on a rock, forming the bank of a brook, which is the only instance of sculpture found by the doctor on rocks *in situ*.

A visit to Costa Rica did not produce any results of interest. The largest field for archæological discoveries is considered by Dr. Habel to be found in San Salvador, and an account is given of several sculptures and mounds he examined there.

Leaving Central America, Dr. Habel visited parts of Colombia, Ecuador, and Peru, which he found rich in architectural structures erected by the ancient inhabitants. Descriptions and measurements of some of these are given in the memoir.

The author, however, as we have said, devotes the principal part of this work to a description of the monoliths at Santa Lucia Cosumalhuapa, a small town in the Department of Esquintla, near the base of the volcano del Fuego, at the commencement of the slope which extends from the mountain range to the Pacific coast. The village is of comparatively modern origin and is in the midst of an extensive orange-grove, which yields so abundantly that the fruit is almost given away, and the great number of trees is accounted for by the custom prevailing of planting a tree by each head of a family at the birth of each child. A short time before the arrival of Dr. Habel in the country the monoliths had been discovered by a man who, in digging a field to prepare the ground for planting cotton, came upon a large pile of stones which, on examination, were found to be sculptured. To make drawings of these was no easy task, for the dirt and moss attached to them had to be removed—a very tedious work. To secure true copies of the originals, strings were stretched over each slab, six inches apart, thus dividing them into squares. The sketch-book was ruled in squares of half an inch, and in each of these a copy of a square of the slab was drawn, making the drawings all one-twelfth the linear size of the original. The slabs form an extended heap, rendering it probable that there are others hidden from view which further researches would reveal. All the sculptures are in low relief, nearly all being in *cavo-relievo;* that is, surrounded by a raised border. In seven instances the sculpture represents, according to the author, a person adoring a deity of a different mythological conception in each case. One of these seems to represent the sun, another the moon, while the character of the others it is impossible to define. These deities are represented by a human figure, of which the head, arms, and breast are correctly portrayed. Four of the other sculptures represent allegorical subjects. The stones on which the low reliefs are sculptured came from the volcano of Ocatenango, and most of them are 12 feet in length, 3 feet in width, and 2 feet in thickness. Nine feet of the upper part of these stones are occupied by sculptures, while the lower 3 feet appear to have served as a base. Very minute descriptions are given of each of these sculptures, and an attempt is made by the author to explain the significance of all the emblems, ornaments, figures, &c., forming the design on each slab.

The author also indulges in speculations as to the origin and symbolism of the sculptures, which are ingenious, novel, and many of them apparently very reasonable, while others will undoubtedly be accepted with much hesitation, and will perhaps be rejected as untenable by students of archæology.

The author was invited to visit Washington, where a room was pro-

vided for him at the Institution and the drawings of these sculptures were reproduced by an artist under his personal supervision and constant instruction. The expense of the preparation of the manuscript and illustrations as well as of the publication has been borne by the Smithsonian Institution. The publication of the work was recommended by several of the leading archæologists of the country, and in a report in regard to it Prof. W. D. Whitney remarks, "It seems to me a story refreshing by its brevity and simplicity, very unlike the pompous and boastful way in which such things are often heralded. One may not agree with all the inferences drawn at the end, but that is a matter of very small importance; no two persons would arrive at precisely the same conclusions. So far as I can judge, the Institution has every reason to take pleasure and pride in the issue of such a contribution to American archæology." The sculptures represented are of such a remarkable character that it has been thought advisable to institute some further inquiries in regard to their present condition; and, fortunately, an opportunity has occurred which enables the Institution to do this without making any draft upon its income. The Government of Guatemala having requested the Government of the United States to nominate a competent geologist to make explorations of mines in the former country, the Secretary of State referred the matter to the Secretary of the Smithsonian Institution, who nominated Mr. Arnold Hague, who had been engaged on the survey of the fortieth parallel under Clarence King, a gentleman well qualified to discharge the duties intrusted to him. He has been requested to visit the region in question and to report on the state of the sculptures described in the memoir of Dr. Habel as well as on any archæological remains of interest which he may meet with in the course of his explorations in the country.

In previous reports a paper has been mentioned which is the result of the investigations of the late Prof. Henry J. Clark relative to *Lucernaria*, a class of animals formerly regarded as *polyps*, but more recently associated with the *acalephæ* or sea-nettles and jelly-fishes. It was presented to the Institution several years ago, but the publication has been delayed by a series of unexpected hindrances. Much delay was experienced at first in obtaining proper engravings of the very minute and complicated drawings to illustrate the work, and before these were completed the author was called from this life, in the flower of his age and in the midst of a series of successful investigations. After his death it was found difficult to obtain the services of a person sufficiently acquainted with the subject to read the proof-sheets, but during the year the printing has been commenced under the supervision of Prof. A. E. Verrill, of Yale College. Unfortunately, another delay has been occasioned by the ill-health of this gentleman. We hope, however, that the work will be completed in the course of a month or two and will be ready for distribution at an early day.

During the year 1877, a paper has been published in the "Contributions to Knowledge" on the "Internal structure of the earth considered as affecting the phenomena of precession and nutation," by General J. G. Barnard, United States Army. This is a supplementary article to one by the same author published in the nineteenth volume of Contributions, and was read before the National Academy of Sciences at its session in April, 1877.

For several years past Mr. P. P. Carpenter, author of the "Lectures on Mollusca," and the "Mollusks of Western North America," published by the Institution, has been engaged in the preparation of a monograph of the *Chitonidæ*, or coat-of-mail shells, a remarkable group of shell-fish. An appropriation was made in 1877 to enable him to have drawings prepared of rare type-specimens in Europe. We regret to state, however, that before his work was completed Mr. Carpenter died at Montreal, on the 24th May, 1877. He was the son of the well-known Dr. Lant Carpenter, and a member of a family distinguished by great gifts. He was born in Bristol, England, in 1819, and after graduating at the University of Edinburgh became a minister of the gospel. He early manifested a taste for natural history, particularly of the mollusks, which he made his special study during his life. He presented to the British Museum his own collection of shells, consisting of 8,873 specimens, all determined, and many of them described by himself. In 1859 he visited America, where he was engaged in determining the collections of shells in the Smithsonian Institution and other museums. His manuscripts were left in an imperfect condition, and partly written in an obsolete phonographic short-hand. An attempt at having this short-hand deciphered is being made, by the help of his brother, the Rev. Russell L. Carpenter, of Bridport, England. A large number of beautiful drawings of the shells and soft parts of the various genera had been prepared at the cost of the Institution, and the manuscript, or such portions of it as may be made available, have been placed in the hands of Mr. W. H. Dall for revision, with a view to their ultimate publication. It is believed that this monograph will form a valuable contribution to the knowledge of the invertebrate animals of the world.

In the report for 1875 it was stated that 184 pages had been stereotyped of the Botanical Index prepared by Prof. Sereno Watson. This work is intended to facilitate the labors of botanists, especially in the study of the plants of the western portions of the United States, by furnishing references to all the published descriptions of species of the flora of North America with lists of synonyms. The search for what has been written frequently consumes more time and labor than all the rest of a botanical investigation, and the present work has been undertaken at the urgent solicitation of some of the principal botanists of the country, who have also contributed to the expense of its preparation. Other duties of Professor Watson have been so engrossing that

he has not yet been able to complete this work. It is now proposed, as recommended by Professor Gray, to publish the pages already stereotyped, as part 1, since this will cover the ground of volume 1 of Torrey and Gray's Flora of North America and be complete in itself as far as it goes. A short preface will be given, and at the end an index to the genera. It will include nearly 500 pages, and can be printed and distributed early in the year 1878.

The "Toner Lectures" have been instituted at Washington by Dr. Joseph M. Toner, a practicing physician of this city, who has placed in charge of a board of trustees, consisting of the Secretary of the Smithsonian Institution, the Surgeon-General of the United States Army, the Surgeon-General of the United States Navy, and the president of the Medical Society of the District of Columbia, a fund, the interest of which is to be applied annually for a memoir or essay relative to some branch of medical science, and containing some new truth fully established by experiment or observation. As these lectures are intended to increase and diffuse knowledge, the Institution has accepted them for publication in its series of "Miscellaneous Collections." The following is a list of the lectures already published:

1. On the structure of cancerous tumors and the mode in which adjacent parts are invaded. By Dr. J. J. Woodward. November, 1873. 44 pp. 8vo.

2. The dual character of the brain. By Dr. C. E. Brown-Séquard. January, 1877. 25 pp. 8vo.

3. Strain and overaction of the heart. By Dr. J. M. Da Costa. August, 1874. 32 pp. 8vo.

4. A study of the nature and mechanism of fever. By Dr. Horatio C. Wood. February, 1875. 48 pp. 8vo.

5. On the surgical complications and sequels of the continued fevers. By Dr. W. W. Keen. April, 1877. 72 pp. 8vo.

6. Subcutaneous surgery; its principles and recent extension in practice. By Dr. William Adams. May, 1877. 20 pp. 8vo.

Of the above series, the second, fifth, and sixth have been published during the past year. The second, by Dr. Brown-Séquard, was not printed in its regular order on account of the failure of the author to furnish the manuscript of the lecture, and it was finally published from short-hand notes taken at the time by a reporter.

Appended to the lecture of Dr. Keen on fever is a bibliography, including works referring more or less briefly to several diseases, viz: 1, diseases of the joints; 2, diseases of the bones; 3, diseases of the larynx; 4, gangrene; 5, hæmatomata; 6, diseases of the eye; 7, phlegmasia; 8, miscellaneous.

To defray in part the cost of printing these lectures, they are sold at 25 cents each.

The records of scientific discoveries have become so extended and so distributed among works forming whole libraries, that to become

acquainted with what is known in any branch, would be a labor of such magnitude as to form a serious obstacle to the advance of knowledge were not means devised for facilitating this labor. The means adopted for this end are classified indexes of special subjects in which may be found everything of importance which has been published in regard to the subject.

The Royal Society's Catalogue of Scientific Papers is a boon to science, and is of great importance to every original investigator, but it is arranged solely under authors' names, and contains only references to papers appearing in periodicals published since 1800, excluding all books published separately. To supplement this the Institution has published during the year an index of books and memoirs relating to nebulæ and star clusters, by Prof. E. S. Holden, of the Washington Observatory. This index includes all papers, memoirs, and books on nebulæ and clusters alphabetically arranged according to authors, giving, for each reference, volume and page. Where the title of a book or paper explains the subject of it, such title is, in general, alone given. Where a paper is quite important its title is given, and if necessary, a note more or less brief, expressive of its contents. The works of the elder Herschel on these subjects are analyzed at considerable length, in order partly to supply the great want of an edition of his collected works. In the case of papers of minor interest, a reference to the periodical, volume, and page is alone given (no title), and a note of its purport. In addition to this, there is given a very condensed reference to the papers in each periodical consulted. In this way a person consulting the catalogue will find all the works of any author upon the general subject, with brief notes of the contents of each paper; or again, any person desiring to refer to the various papers on this subject contained in any serial publication, as the Philosophical Transactions, for example, will find references which will save him much time. The index is practically complete to the present date; it contains a complete list of all published (and many unpublished) drawings of nebulæ and clusters, and also an index to Sir William Herschel's classes of nebulæ.

In the last two reports an account was given of a new series of publications to form part of the "Miscellaneous Collections," entitled "Bulletins of the National Museum," and intended to illustrate the collections of natural history and ethnology belonging to the United States, of which the Smithsonian Institution is the custodian. They are prepared at the request of the Institution by different individuals, and are printed, by the authority of the Secretary of the Interior, at the Government Printing Office.

Since the date of the last report, numbers 7, 8, and 9 of the Bulletins have been published.

No. 7 is a contribution to the Natural History of the Hawaiian and Fanning Islands and Lower California, by Dr. Thomas H. Streets, passed assistant surgeon, United States Navy. The collection that furnished

the materials for this Bulletin were made by Dr. Streets while connected with the North Pacific Surveying Expedition in 1873–'75. The Fanning group consists of four small coral islands, Christmas, Fanning, Washington, or New York, and Palmyra. They are situated immediately north of the equator, extending from latitude 1° 57′ north to 5° 49′ north, and from longitude 157° 27′ west to 162° 11′ west. Three of these islands have been *terra incognita* to the naturalist, and furnish much new matter. This was particularly the case with Washington Island, which is an obliterated atoll, having been lifted up by some disturbing force, so as to close up the lagoon-outlet, and what was the old salt-water lagoon is now a fresh-water lake. It is probable that the salt-water of the lagoon has drained off through the light, porous soil, and its place been supplied by rain-water. It is unfortunate that the exigencies of the naval service did not permit of a longer stay at this island, and especially that sufficient time was not given to investigate the life in the fresh-water lake. During the half day which he was allowed to remain on the island, Dr. Streets succeeded in fixing the habitat of a lory (*Coriphilus kuhli*), which has long been a puzzle to ornithologists, and he also discovered a diminutive species of the gadwell duck inhabiting the lake. The specimens of the lory brought home by Dr. Streets are, it is believed, the only ones in this country; and they are exceedingly rare in the museums of Europe. The island is densely covered with vegetation, the cocoanut-palm tree predominating. The collection represents the complete avi-fauna of the group during the winter months, with two or three exceptions. A point of interest in connection with the fish collection is that it extends the area of distribution of many species that were previously confined to the East Indian region. The conditions surrounding life on the southernmost island of the group, Christmas, were generally found to be very different from that on the others; and in cases where it was the same, the habits of the species were observed to be greatly modified. The notes accompanying the names of the sea-birds are thought to be very interesting in this connection. Purely land-life, as is natural to be supposed, is very scantily represented on the islands. On Palmyra there was found a minute shell, a *Tornatellina*, and a land-leech, that fastened itself upon the eyelids of the young birds. Rats and house-flies are abundant, but neither are indigenous. In addition to the land-birds already mentioned, there was also observed on Washington a bird resembling a fly-catcher. Giant land-crabs were numerous on the same island.

After the Portsmouth, on which Dr. Streets was stationed, had completed the survey of the Fanning group, he was transferred to the Narragansett, which was making a survey of the west coast of Mexico. This portion of the collection does not pretend to be exhaustive even of any one locality, the nature of the work, a running survey, precluding the idea of a protracted stay in one place. The elucidation of some doubtful points in the history of two species of birds and an account

of the guano deposits in the Gulf of California are the only noteworthy items in connection with the ornithology of this region. Angel Island in the Gulf, was found to be the dwelling-place of two extremely rare Arizonian reptiles. In regard to fish, two more species are added to the number of those that are common to both the Atlantic and Pacific shores of the American continent.

The eighth number of the Bulletin is an index to the names which have been applied, previous to the year 1877, to the subdivisions of the class Brachiopoda excluding the Rudistes, by William H. Dall, of the United States Coast Survey. The Brachiopods are among the most characteristic forms by which geological strata are co-ordinated. Many genera have been described in little-known works by European authors, and many others in obscure American publications. Most of the names applied to these genera are duplications of one another. American and European authors have been retarded in their classification of the Brachiopods by this undigested synonymy. Mr. W. H. Dall has collected the history of all the names which have been applied to members of this group both properly and improperly, and added notes on their synonymy, relations and a geological table of the strata in which each group is found. This index affords the means for properly naming the national collection of these fossils, and it has received the approbation of Mr. Thomas Davidson, F. R. S., of England, the highest authority living on the subject of Brachiopoda. It is shown by this list that of sixteen families of Brachiopods, six have living representatives, one more than appear to have been represented during the Cambrian epoch, while but two of the Cambrian families have survived. All those living in Cretaceous times have endured till now. All now living had Paleozoic representatives, while half the Paleozoic families do not appear to have survived the changes which introduced the Mezozoic time. This work is an octavo of 88 pages.

The ninth Bulletin is entitled "Contributions to North American Ichthyology based primarily on the collections of the United States National Museum. Part I. Review of Rafinesque's Memoirs on North American Fishes." By Prof. D. S. Jordan. The object of the author of this paper is to present a series of identifications of the species of fresh-water fishes described by Rafinesque in his "Ichthyologia Ohiensis" and elsewhere, the result of nearly three years of field-work in the region explored by Rafinesque. It forms an octavo pamphlet of 53 pages.

Annual report.—The annual report of the operations of the Institution for the year 1876, was presented to Congress on the 16th day of February, 1877, and on the 28th of February a resolution was adopted by Congress ordering an edition to be printed of 10,500 copies, of which 1,000 were to be for the use of the Senate, 3,000 for the House of Representatives, and 6,500 for the use of the Institution. This was a reduction in the number usually ordered for distribution by the Institution of 1,000 copies.

The appendix to the report for 1876 contains translations of Arago's Eulogy on Gay-Lussac; Fialho's Biographical Sketch of Dom Pedro I; Pilar on the Revolutions of the Crust of the Earth; and Blondel on Jade; besides original articles on Kinetic Theories of Gravitation, by William B. Taylor; the Asteroids between Mars and Jupiter, by Prof. Daniel Kirkwood; the Latimer Collection of Antiquities from Porto Rico, by Prof. Otis T. Mason; Antiquities in Guatemala, by the Hon. George Williamson; Collections of Historical Documents in Guatemala, by Dr. C. H. Berendt; Observations on the Prehistoric Mounds of Grant County, Wisconsin, by Moses Strong; Deposits of Flint Implements, by Dr. J. F. Snyder; Ancient Mica Mines in North Carolina, by C. D. Smith; a Double-walled Earthwork in Ashtabula County, Ohio, by Stephen D. Peet; an Ancient Implement of Wood, by E. W. Ellsworth; Centennial Mission to the Indians of Western Nevada and California; Indian Forts and Dwellings, by Dr. W. E. Doyle; and the Sioux or Dakota Indians, by Col. Albert G. Brackett.

ANTHROPOLOGY.

Anthropology, or what may be considered the natural history of man, is at present the most popular branch of science. It absorbs a large share of public attention and many original investigators are assiduously devoted to it. Its object is to reconstruct, as it were, the past history of man, to determine his specific peculiarities and general tendencies. It has already established the fact that a remarkable similarity exists in the archæological instruments found in all parts of the world with those in use among tribes still in a savage or barbarous condition. The conclusion is supported by evidence which can scarcely be doubted, that by thoroughly studying the manners and customs of savages and the instruments employed by them, we obtain a knowledge of the earliest history of nations which have attained the highest civilization.

It is remarkable in how many cases customs existing among highly civilized peoples are found to be survivals of ancient habits. Indeed it is asserted, and with at least apparent truth, that every unmeaning ceremony found in rural life in Europe and America, is a survival of an important custom connected with an essential condition of life in the aboriginal race. Hence, to clearly apprehend the manners and customs of modern society, it is necessary to study them in connection with the myths, the ceremonies, and the usages of ancient people.

American anthropology early occupied the attention of the Smithsonian Institution. To collect all the facts which could be gathered in regard to the archæology of North America, and also of its ethnology, or, in other words, an account of its present Indian inhabitants, was considered a prominent object in the plan of operations of the establishment. The first volume of its Contributions, whereby its plan of intended operations was illustrated, consists of an elaborate and expensive work on the "Ancient Monuments of the Mississippi Valley"; and from the time of

the publication of this volume until the present, contributions of value have been made annually by the Institution to this branch of knowledge.

During the past year small appropriations were made as usual for opening mounds and collecting their contents, and larger ones to Mr. F. A. Ober, for archæological explorations in the West Indies, and Stephen Bowers for similar operations in California. The former gentleman has succeeded in finding remnants of the ancient Carib tribes, and has obtained photographs of the people and specimens of their handiwork. His exploration bids fair to produce a valuable return for the money expended. It is not confined to ethnology, but embraces collections in all branches of natural history.

The exploration by Mr. Bowers was a continuation of one undertaken in connection with Major Powell, and was made in the vicinity of Santa Barbara and on the islands adjacent to Lower California. From this exploration forty boxes of very interesting relics of the ancient inhabitants of this country have been received. A full report of these will be prepared by Major Powell. The entire series of objects obtained become the property of the National Museum.

As will be seen from the exhibit of the executive committee, the whole amount of money devoted to explorations during the year is $879.50.

The collection of the archæology and ethnology of America in the National Museum is the most extensive in the world; and, in order to connect it permanently with the name of Smithson, it has been thought advisable to prepare and publish at the expense of the Smithson fund an exhaustive work on American anthropology, in which the various classes of specimens shall be figured and described.

For this purpose Mr. Charles Rau, formerly of New York, well known for his contributions to American archæology, has been employed to take charge of the work, with the assistance of skilled artists. He is furnished with rooms in the building, and now devotes one-half of the time to the arrangement of the archæological museum, and the other to the description of the specimens and the direction of the artists engaged in delineating them.

The Institution has also lately entered upon a project it has long had in contemplation, namely, the compilation of a map of the distribution and character of the archæological remains of North America. The preliminary arrangements for this work have been intrusted to Prof. Otis T. Mason, of Columbian University, who has prepared a circular which wil soon be published by the Institution.

In the last report it was stated that the large collection of Indian vocabularies in possession of the Institution had been transferred to Prof. J. W. Powell, to be incorporated with his series in his general work on the ethnology of the Territories of the United States in course of preparation and publication by the Interior Department. What has been accomplished during the past year in relation to this work will be seen in Professor Powell's account of his explorations, given in the appendix to the report of the Secretary.

Reference was made in the last report to the "Instructions for research relative to the ethnology and philology of America," prepared in 1861 by Dr. George Gibbs, and the fact was stated that a new edition of this work had been undertaken in behalf of the Institution by Professor Powell. During the year 1877, a volume entitled "Introduction to the Study of Indian Languages" has been printed, and a few copies distributed among those interested in the study of Indian languages for such additions and emendations as may be suggested preparatory to final publication. In its preparation Professor Powell was assisted by Prof. W. D. Whitney, the distinguished philologist.

METEOROLOGY.

The Institution during the past year has continued its labors in the line of the reduction of meteorological observations. It has been especially engaged in the discussion of material for a new edition of the Rain-fall Tables for North America. It has also reduced and printed the observations made by Professor Caswell at Providence, from the termination of his series of meteorological observations published in 1860 down to the close of 1876, the whole making a continuous series for a period of forty-five years. Long series of this kind are of great importance in determining any change of climate which may have occurred during the period which they embrace.

We mention in regard to this series an interesting fact in connection with the supposed change in the rain-fall in different parts of the United States due to the clearing off of forests. If, for example, we take from this series three ten-year periods, one at the beginning, one at the middle, and one at the end, we observe a regular increase instead of diminution in the amount of rain-fall in Providence, as shown by the following figures:

From 1832 to 1841, average 38 inches.

From 1852 to 1861, average 44 inches.

From 1867 to 1876, average 49 inches.

This fact, however, may be in some way connected with the custom which, I am told, has become common in New England since the inhabitants have devoted themselves largely to manufactures, of allowing a considerable portion of the soil which was formerly under cultivation to grow up in wood.

The next series of observations which remains to complete the results of the whole meteorological system of the Smithsonian Institution will be that on the pressure of the atmosphere, which is intimately connected with the dominant winds in different parts of the country.

The miscellaneous work by the meteorological computers of the Institution during the year 1877, is as follows:

1. Tabulating the mean temperature and the maxima and minima of temperature for the Smithsonian stations for the years 1871-'72-'73.

2. Tabulating rain-fall, temperature, and maxima and minima for Canadian stations, 1875.

3. Tabulating rain-fall for Signal-Service stations, January, 1875, to July, 1876.

4. Making corrections and additions to rain-fall manuscript.

5. Making indices to the rain-fall and maxima and minima tables.

TELEGRAPHIC ANNOUNCEMENT OF ASTRONOMICAL DISCOVERIES.

The arrangement which was established between the Smithsonian Institution and the Atlantic cable companies in 1873, by which free telegraphic transmission of astronomical discoveries was granted between Europe and America, has been continued during the past year.

The following is a list of the small planetoidal bodies discovered in 1877:

Number.	Name.	Discovered—	By—	At—
170	Myrrha	Jan. 10, 1877	Perrotin	Toulouse.
171	Ophelia	Jan. 13, 1877	Borelly	Marseilles.
172	Baucis	Feb. 5, 1877	do	Do.
173		Aug. 2, 1877	do	Do.
174		Sept. 2, 1877	Watson	Ann Arbor.
175		Oct. 1, 1877	do	Do.
176	Iduna	Oct. 14, 1877	Peters	Clinton.
177		Nov. 5, 1877	Paul Henry	Paris.
178		Nov. 6, 1877	Palisa	Pola.
179		Nov. 11, 1877	Watson	Ann Arbor.
180 (?)	Eva (?)	Dec. 29, 1877	Palisa	Pola.

NOTE.—*Lumen* (141) was independently discovered by Watson and Borelly in August, and *Athor* (161) by Palisa in October.

EXCHANGES.

The literary and scientific exchanges inaugurated by the Institution have increased during the past year in a greater ratio than ever before. Four hundred and six boxes, averaging 7 cubic feet each, with a total weight of nearly 100,000 pounds, and containing over 15,000 separate parcels, were sent abroad by the Institution. During the year, 4,870 packages, each containing several articles, have been received from abroad for distribution in this country.

To show the high estimation in which this branch of the operations of the Institution is held, as well as to give proper credit to the parties who forward free of charge the packages of the Institution, we republish, as usual, the following list:

Cunard Steamship Company.
Anchor Steamship Company.
Pacific Mail Steamship Company.
Panama Railroad Company.
Pacific Steam Navigation Company.
New York and Mexico Steamship Company.
New York and Brazil Steamship Company.
North German Lloyd Steamship Company.
Hamburg American Packet Company.
North Baltic Lloyd Steamship Company.
Inman Steamship Company.

The special thanks of the Institution are again tendered to the above-mentioned companies for their enlightened liberality.

We may also mention as an evidence of the high appreciation of the character of the Smithsonian exchanges, that the packages bearing the marks of the Institution are admitted free of duty into all foreign ports

The following are the principal foreign agencies of reception and distribution of the Smithsonian exchanges:

London, William Wesley, 28 Essex street, Strand.
Paris, G. Bossange, 16 Rue du 4 Septembre.
Leipsic, Dr. Felix Flügel, 49 Sidonien Strasse.
St. Petersburg, L. Watkins & Co., 10 Admiralty Place.
Amsterdam, Frederick Müller, Heerengracht KK. No. 130.
Milan, U. Hoepli, 591 Galeria Cristoforia.
Harlem, Professor von Baumhauer.
Christiania, Royal University of Norway.
Stockholm, Royal Swedish Academy of Sciences.
Copenhagen, Royal Danish Society.
Lisbon, Polytechnic School.
Madrid, Royal Academy of Sciences.
Havana, Dr. Felipe Poey.
Santiago, University of Chili.
Mexico, Mexican Society of Geography and Statistics.
Montreal, Geological Survey of Canada.

The packages of the Institution for the West Indies have been kindly forwarded by Mr. Thomas Bland, of New York, and those for Turkey, by Messrs. Chrysoveloni & Co., of 5 Fenwick street, Liverpool, England; and those for other points in the East, by the American Board of Commissioners for Foreign Missions, Boston.

The following table exhibits the number of foreign establishments with which the Institution is at present in correspondence, or, in other words, to which it sends publications and from which it receives others in return.

Foreign institutions in correspondence with the Smithsonian Institution.

Algeria	6	Italy	187
Argentine Republic	14	Japan	6
Australia	32	Java	5
Belgium	113	Liberia	1
Bolivia	1	Mauritius	3
Brazil	10	Mexico	16
British America	20	New Zealand	15
British Guiana	3	Norway	25
Cape Colony	5	Peru	4
Central America	2	Philippine Islands	3
Chili	8	Polynesia	2
China	1	Portugal	32
Colombia	3	Russia	162
Denmark	29	Spain	24
Dutch Guiana	1	St. Helena	2
Ecuador	1	Sweden	21
Egypt	8	Switzerland	73
France	327	Turkey	12
Germany and Austria	661	Venezuela	2
Great Britain and Ireland	368	West Indies	8
Greece	8	General	7
Holland	65		
Iceland	4	Total	2,330
India	30		

Statistics of exchanges sent during the last nine years.

	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
Number of boxes	112	121	108	179	196	131	208	323	397
Bulk in cubic feet	1,033	1,189	772	954	1,476	933	1,503	2,261	2,779
Weight	23,376	31,383	28,950	26,850	44,236	27,990	45,300	80,750	99,250

To facilitate the business of the exchanges, the following rules have been adopted:

1. Every package, without exception, must be enveloped in strong paper, and secured so as to bear separate transportation by express or otherwise.

2. The address of the institution or individual, for whom the package is intended, must be written legibly on the cover, and the name of the sender on one corner of the same.

3. No single package must exceed half of a cubic foot in bulk.

4. A detailed list of addresses of all the parcels sent, with their contents, must accompany them.

5. No letter or other communication can be allowed in the parcel, excepting such as relates exclusively to the contents of the package.

6. All packages must be deli vered in Washington free of freight and other expenses.

7. Every parcel should contain a blank acknowledgment, to be signed and returned, either through the agent of the Institution, or, what is still better, through the mail, to the sender.

Should returns be desired for what is sent, the fact should be explicity stated on the list of the contents of the package, as, unless these are specifically asked for, they will fail in many instances to be made.

Specimens of natural history will not be received for transmission unless with a previous understanding as to their character and bulk.

8. Unless all these conditions are complied with, the parcels will not be forwarded from the Institution; and, on the failure to comply with the first and sec ond conditions, will be returned to the sender for correction.

A new edition of the list of foreign correspondents of the Institution is now in press and will be distributed to libraries &c., in the course of a few weeks.

EXCHANGE OF GOVERNMENT DOCUMENTS.—In the report for 1875 a full account was given of the system adopted for carrying out the law relative to the exchange of the official publications of the United States Government for those of foreign nations. In accordance with this system, during the past year, 71 boxes of documents were forwarded, the following being a list of the distribution:

International exchange of government publications in 1877.

	Boxes.		Boxes
Argentine Republic	3	Canada	2
Belgium	2	Portugal	2
Brazil	2	Prussia	2
Buenos Ayres	2	Queensland	2
Chili	2	Saxony	2
England	2	Scotland	2
France	3	Spain	2
Germany	2	South Australia	2
Greece	7	Sweden	2
Hayti	3	Switzerland	2
Holland	2	Tasmania	2
Japan	2	Turkey	2
Mexico	2	Venezuela	3
New South Wales	2	Victoria	2
New Zealand	2		
Norway	2	Total	71
Ontario	2		

The expense of boxing, packing, transporting, and payment of agents in connection with the transmission of these governmen t documents has been advanced for two years by the Institution, but it is expected that Congress will reimburse it by an appropriation at the present session.

LIBRARY.

Statement of the books, maps, and charts received by the Smithsonian Institution in 1877, *and transferred to the Library of Congress.*

Volumes:		
Octavo, or less	1,328	
Quarto, or larger	561	
		1,889
Parts of volumes:		
Octavo, or less	1,954	
Quarto, or larger	2,373	
		4,327
Pamphlets:		
Octavo, or less	1,754	
Quarto, or larger	430	
		2,184
Maps and charts		326
Total		8,726

An increase of 1,141 over the year 1876.

List of the more valuable books received in 1877.

From the British Museum, London: Fac-simile of an Egyptian Hieratic Papyrus, of the reign of Rameses III. London, 1876. Oblong Elephant folio.—Fac-similes of Ancient Charters. Parts ii, iii. 1876–1877. Folio.—Catalogue of Sanskrit and Pali books. By Dr. E. Haas. 1876. 4to.—Catalogue of Oriental Coins. Vol. ii. 1876. 8vo.—Catalogue of Greek Coins. Sicily, 1876. 8vo.—Catalogue of the Fossil Reptilia of

South Africa. By R. Owen. 1876. 8vo.—Catalogue of Birds. Vol. iii. 1877. 8vo.

From the Royal Society of Northern Antiquaries, Copenhagen: Antiquités Russes d'après les Monuments historiques des Islandais et des anciens Scandinaves. Vols. i, ii. Copenhagen, 1850–1852. Folio.—Aarboyer for 1875–1876. 7 parts. 8vo.

From the Royal Prussian Mining Office, Breslau: Geologie von Oberschlesien, with atlas, charts, and profile. Breslau, 1870. 4to. (8 copies.)—Uebersicht über die Production der Bergwerke, Salinen und Hütten im Preuss. Staate im Jahre, 1876. Berlin, 1877. 4to.—Montanstatistik des deutschen Reichs und Luxemburgs, &c., 1875. Berlin, 1877. 4to.—Vierteljahrshefte zur statistik des deutschen Reichs für das Jahr, 1873. Berlin. 4to.

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LABORATORY.

During the summer the laboratory was closed, Dr. Endlich, the mineralogist of the Institution, having been engaged on the survey under Dr. Hayden. Mr. Fred. W. Taylor of this city occupied the laboratory for some time in the autumn, and made analyses of mineral waters and specimens of ores, &c., which had been sent to the Institution for examination.

As specimens are constantly being received by the Institution from all parts of the country, with the request that a report be made as to their character or constituents, it may be well to call attention to the rules adopted for their examination.

1. *Qualitative* examinations, that is, for determining the constituents of the specimens, are made without charge.

2. *Quantitative* examinations, or the determination of the percentage of the different components of the specimens, can only be made at the expense of the applicant; the charge to be in proportion to the time expended in the work, *e. g.*, from $5 to $50, according to whether it is *partial* (determination of silver, lead, or iron, &c., only), or *full* (determination of every thing).

3. The report of *quantitative* examinations will be given under the name of the *expert* to whom the specimen shall be submitted, and not under that of the Smithsonian Institution.

4. All applications for the determination of specimens must be made by letter, addressed "Secretary of the Smithsonian Institution."

5. The specimens examined, or part of them, will be retained by the Institution.

6. All specimens to be delivered to the Institution free of expense.

NATIONAL MUSEUM.

The National Museum was established by the Government in 1842, at which time it consisted principally of specimens collected by the Wilkes exploring expedition. It was transferred from the Patent Office to the care of the Smithsonian Institution in 1858, where it has been enlarged by all the collections made by exploring and surveying parties of the several bureaus of the War, Navy, Treasury, and Interior Departments, and those of the Smithsonian Institution.

The following report from Professor Spencer F. Baird, assistant secretary, gives an account of the additions to the museum and the various operations connected with it during the year 1877:

REPORT OF PROF. SPENCER F. BAIRD ON THE MUSEUM.

Increase of the Museum.—It was hardly to be expected that the additions to the National Museum in 1877 should compare with those of 1875 and 1876, including, as they did, the results of large expenditures for the purpose of making a suitable exhibit at the International Exhibition of 1876 of the ethnology and of the resources of the United States, as derived from the animal and mineral kingdoms, with their accessories. The reduction in the yield, however, proves to be much less marked than was anticipated; and the aggregate of receipts has been far beyond that of any previous year, with the exception of those mentioned. The number of donors was 342, of donations 489, and of separate packages 815.

As heretofore, the additions to the Museum consisted of five classes: First, those supplied by the different government expeditions, in accordance with the law of Congress. Second, the donations from private individuals, made either spontaneously, or in response to special invitations and requests. Third, the results of exchanges, prosecuted with various establishments or individuals at home and abroad. A fourth

source of supply is from explorations made at the expense of the Smithsonian Institution. A fifth source of increase is from purchase, which, however, is very insignificant, and is principally confined to specimens of animals obtained in market or occasionally a single ethnological implement, offered under specially favorable circumstances. It is in this that the National Museum differs most from establishments of its grade throughout the world, which depend very largely upon purchases to secure desired materials. Here, on the contrary, the space and force at command are all fully required to receive and care for the collections that are continually arriving from the sources referred to.

In view of the limited accommodations for the collections and of the small appropriations for their maintenance, the special efforts toward the extension of the National Museum have been restricted, for the most part, to North America and to the most interesting subject of research at the present day, that of American anthropology. Every possible effort has been made to invite contributions of facts and materials on this subject, and with very gratifying success. The intention of the Smithsonian Institution to publish, whenever the proper means can be obtained, an exhaustive treatise on American archæology, with suitable illustrations, has invoked the co-operation of many persons who desire to see such an end accomplished; and especially as the Institution proposes to give, under each group, an enumeration of the principal articles received, arranged by localities and donors.

Few portions of the country have been without representation in the ethnological donations of the year; although certain regions have been more prolific than others. The largest additions from any one source have resulted from the continued explorations of Rev. Stephen Bowers on the main-land in the vicinity of Santa Barbara, and on the adjacent islands of Southern California; over forty boxes of material having been supplied by him alone. This exploration was made under the auspices of Maj. J. W. Powell, with the co-operation of the Smithsonian Institution. An exhaustive report on the subject will be published by Major Powell, the collections themselves becoming the property of the National Museum.

With the material heretofore gathered in the same region, by Mr. W. G. W. Harford, Mr. W. H. Dall, Mr. Paul Schumacher, and Mr. Bowers himself, it is believed there can never be a better representation of the archæology of the tribes of the California coast than that now in Washington. This embraces a great variety of objects of stone, bone, shell, and wood, representing applications of these substances far in advance of those of any other aboriginal tribes, excepting those of the northwest coast.

The large collections of similar character, made by Mr. Bowers, in 1875, in behalf of Lieutenant Wheeler's survey, have also been transferred, in part, by that office, to the Museum.

From Mr. Lucien M. Turner, late meteorological observer of the signal-

office, at Saint Michaels, Alaska, there has been received a continuation of his extremely important collections of objects manufactured and used by the Esquimaux of Alaska. This collection is especially rich in carvings on bone and walrus ivory, representing scenes and incidents in the life of that people.

The Institution is indebted to Mr. F. Hirst, of Bridger Station, for many interesting articles from the Rocky Mountain region, principally stone implements of various kinds.

Professor Hayden has presented a full series of models of the ancient ruins in New Mexico and Colorado, together with restorations showing what was probably their original character. These have attracted much attention, and the promised continuation of the series affords much satisfaction.

Mr. Frank H. Cushing, assisted by Mr. Henry J. Biddle, of Philadelphia, visited a cave near Hagerstown, Md., and obtained many relics of the aboriginal people who formerly inhabited that vicinity. Numerous implements of stone and bone, articles of pottery, and fragments of the remains of aboriginal feasts, &c., were collected and are now in process of careful investigation.

The most important yields from the shell-heaps of the United States were obtained from the shell-mounds of Mobile, by Colonel Gaines and Mr. K. M. Cunningham, of that city. These consist of numerous articles of pottery, some of them quite peculiar in form, and of a material and ornamentation constituting almost a distinct class in aboriginal ceramics. With these were also various articles of bone, stone, &c., the whole making one of the most important contributions of the kind yet secured by the National Museum.

From numerous localities in the interior have been received single specimens or collections, partly from mounds, partly from graves, and partly from the superficial soil. These will be referred to in more detail in the list of donations. Among the more noteworthy are those presented by Colonel McAdoo and Mr. McKinley, from Georgia; Mr. Perrine, from Illinois; Mr. Brodnax and Dr. James, from Arkansas; Mr. Illigg and Mr. Berlin, from Pennsylvania, and others.

A great many possessors of rare and curious objects, indisposed to part with them permanently, have freely lent them to the Institution, for the purpose of having copies made, and several persons have been occupied during a great part of the year in making plaster casts and in painting them from the originals before their return.

A collection of implements received from Mr. Berlin, of Reading, is of peculiar interest as representing, in all probability, the same palæolithic epoch as that which Dr. Abbott has so ably discussed in his paper on the Antiquities of New Jersey, published in the Report of the Smithsonian Institution for 1875.

A most valuable addition to the ethnological collection consisted of a series of casts of the heads and faces of sixty-four Indians, held as pris-

oners of war at Saint Augustine, in Florida, under the charge of the War Department. These were prepared during the summer by Mr. Clark Mills, the well-known sculptor, of Washington, who visited Saint Augustine for the purpose. It is generally difficult to induce an Indian to submit to the discomfort and apparent danger of the treatment required in taking face casts, but these prisoners were easily persuaded by Captain Pratt, United States Infantry, who has them in special charge, to allow the operation, and Mr. Mills was extremely successful in the work. In addition to the heads, a number of separate casts of arms, legs, and busts were taken, thus furnishing a rare opportunity for studying the anatomy of the Indian. The tribes represented are the Kiowas, Comanches, Arapahoes, &c. This collection furnishes not only the means of studying the lineaments of the North American Indian, but also answers the purpose of models for lay figures on which to place the many suits of Indian clothing in possession of the Museum.

Extremely important additions have been received from several of the West India islands during the year, some of them unique and previously more or less unknown. Reference has been made in previous reports to the extremely rich collection of stone implements bequeathed to the National Museum by Mr. George Latimer, and of which an illustrated account by Professor Mason is published in the Smithsonian Report for 1876. Among articles of West Indian archæology received in 1877 are several wooden stools of peculiar shapes, highly ornamented and carved, presented by Dr. William M. Gabb and Mr. Frith; some wooden idols of large size and complex shape, also from Dr. Gabb; a stone celt, with the handle and cutting portion in one piece, from Mr. George J. Gibbs; a stone celt inserted in its original handle, by Mr. Murphy, and a number of specimens of somewhat similar character, belonging to the public library of Nassau, and lent for the purpose of being figured and copied. Some collections of a similar character made by Mr. Frederick A. Ober in Dominica, Antigua, and elsewhere, have not yet come to hand.

Other extra-limital collections received have been a series of very interesting articles of obsidian and stone from the National Museum of Mexico, and some ancient Japanese stone implements from the Tokio Museum in Japan.

Of mammals quite a number of specimens have been received, the most striking of them being a pair each of the blue and white foxes of Saint Paul's Island, Alaska, from the Alaska Commercial Company; the skin of a cinnamon bear, from Mr. F. O. Matteson; skins of antarctic seals, from Captain Fuller; and a skeleton of a porpoise of the genus *Tursiops*, new to the Museum, from Mr. Alfred N. Lawrence; two skeletons of the grampus, from Mr. Small, of Provincetown; alcoholic specimens of Platypus and Echidna from Tasmania, &c.

The collections of birds and their eggs received during the year have been quite abundant, the most noteworthy among them being a speci-

men of the everglade kite of Florida, from Mr. George A. Boardman. Dr. James C. Merrill, assistant surgeon, United States Army, has contributed a large collection of birds and eggs from the Lower Rio Grande, several of them new to science, and others not previously known within the limits of the United States. Mr. Lucien M. Turner and Mr. Nelson, of the United States Signal Service, stationed at Saint Michaels, in Alaska, have also sent in large numbers of the birds of Alaska, including many very rare skins.

A series of the birds of Southern Illinois has been received from Mr. Robert Ridgway. Colonel Brackett and Mr. Hirst have furnished some valuable specimens of birds and eggs from Wyoming. From Lieutenant Wheeler and Dr. Hayden have also been received large numbers of specimens collected in the course of their respective surveys.

The National Museum of Mexico has supplied a large number of species from that country, several of them not before in the collection.

Perhaps the most important contribution of birds is that received from Frederick A. Ober, as the result of the exploration he is now making in the West Indies under the direction of the Smithsonian Institution. These were principally obtained from the island of Dominica, and constitute by far the largest series ever gathered in that island, several representing new species and others previously lacking in the Museum. Mr. Ober is still in the field, and additional contributions from the other West India islands are expected.

The collections of reptiles have consisted in large part of the specimens obtained under the direction of Lieutenant Wheeler and Professor Hayden, and transmitted by those officers. The other additions have consisted principally of turtles and snakes, forwarded at the express request of the Institution, to serve as models in the series of plaster casts now in preparation for the Museum. The more important contributors in this line are Mr. S. N. Ferguson, of the large alligator snapper of the Lower Mississippi; Mr. Kohn, of the turtles in the vicinity of New Orleans; Dr. Merrill, of those from the Rio Grande; Mr. Richard, of those from Pennsylvania, &c.

A very large living diamond rattlesnake was obtained through the assistance of Mr. Way, of Sanford, Fla.; and Mr. Frank W. Heyward, of South Carolina, supplied a number of living specimens of *Siren*.

Of fishes the collections have been very large, embracing, of course, those gathered by the United States Fish Commission during its labors in different portions of the country. The summer's work of the Commission was prosecuted on the coasts of Massachusetts and of Nova Scotia, and in the intermediate seas, extending over the months of July, August, and September. Quite a number of fishes not previously described in the fauna of the country were obtained. Many species in large quantities were gathered to serve the purposes of distribution to museums of the United States.

The collections of marine invertebrates, gathered under the same aus-

pices, are also very large. Other collections made by the commission consisted of series of the fresh-water fishes of the Columbia and Clackamas rivers of Oregon, and the McCloud River of California, gathered by Mr. Livingston Stone; of landlocked salmon and other fishes of Grand Lake Stream, Maine, by Mr. Charles G. Atkins; and a great variety of sea-fishes from Wood's Hole, Massachusetts, by Mr. Vinal N. Edwards, and of the Saint John's River, Florida, by Messrs. Baird and Milner.

A large number of the stomachs of mackerel, collected by Capt. H. C. Chester, furnished the means of solving an important problem in regard to the food of that fish. Collections were also made at various points by Mr. Milner and his assistants of the Commission. Mr. Samuel Powel, of Newport, who has been engaged for several years in collecting the fishes of his vicinity, has added many specimens to those already presented by him to the museum, and furnished much information in regard to the geographical distribution of species.

Captain Hulbert, who was engaged as pilot on the Speedwell during her summer's cruise, obtained and transmitted a new species of chimæra, which is now named *C. plumbea* by Professor Gill. This was taken on a halibut line, at a depth of several hundred fathoms, off the coast of Nova Scotia.

Mr. E. G. Blackford, the well-known fish-dealer of Fulton Market, New York, has continued his valuable contributions, that have now extended over a number of years, securing and supplying to the museum all the rarer and more remarkable fishes received by the New York dealers. A large number of specimens have been sent by him, as enumerated in the list of donations, and furnishing a continued illustration of that public spirit, liberality, and disinterestedness for which we are happy to make a public acknowledgment.

Many specimens of various food-fishes, as salmon, trout, whitefish, and the like, have been sent by different contributors for the purpose of meeting an expressed want or of securing identification.

A very interesting series of contributions during the year has consisted of specimens showing the success of the various efforts made under the direction of the United States Fish Commission for the propagation of food-fishes and their introduction into new waters. Among these may be mentioned a full-grown, true shad caught in the Ohio River at Louisville, being one of six hundred taken during the summer under similar circumstances. These were probably derived from the stock introduced four years previously as young fish into the Allegheny River in Western New York. This was presented by the fish commissioners of Kentucky through Mr. Pack Thomas.

A shad, also the result of the transfer of young fish to California several years ago from the East, was furnished by Mr. Bassett, through Mr. B. B. Redding. The latter gentleman also supplied several specimens of the food-fishes of the Sandwich Islands, of which living specimens

had been transmitted to the commissioners of California for introduction into that State.

A salmon, of about twelve pounds weight, caught in the Delaware River, at Easton, in October, was supplied by Mr. Howard J. Reeder, fish commissioner of Pennsylvania. This was supposed to have been derived from a stock introduced into the river in 1873.

Many other equally interesting cases will be found referred to in the list of donations, and more especially in the report of the United States Fish Commissioner for 1877.

A finely-stuffed skin of the adult Ontario salmon was presented by Mr. Samuel Wilmot, of the Canadian fishery department, at New Castle, Ontario. This was a female, and especially interesting as having furnished a quota of eggs during three successive seasons.

In consequence of an extended exploration of the rivers of Georgia, the Carolinas, &c., prosecuted by Prof. D. S. Jordan, during the last summer, in part under the auspices of the United States Fish Commission, large numbers of species of fish, several of them previously undescribed, were collected, and a series transmitted by Mr. Jordan.

Collections of the fishes of the Great Basin, and of the coast of California, were received from Lieutenant Wheeler, as the result of his gatherings in past years.

Of extralimital species, the most important collection of fishes was one received from Mr. G. Brown Goode, assistant curator of the National Museum, gathered by him during the past winter in Bermuda. Some species from the vicinity of the Kerguelen Islands were presented by Captain Fuller.

Of marine invertebrates, the principal collections were those made by the United States Fish Commissioner. Some of great interest were obtained from Col. E. Jewett, of Santa Barbara, Mr. James G. Swan, in Washington Territory, and others.

The collections of plants were not very extensive; the most important, however, were furnished by Lieutenant Wheeler. A valuable contribution consisted of a series of specimens of Japanese woods, representing fifty species, and presented by the Tokio Museum of Japan. These, taken in connection with fifty other species received by the Smithsonian Institution from the Japanese commission at the Centennial Exhibition, complete the series of woods of Japan.

Fossil remains of more or less rarity and interest are represented by a collection of the Black Hills fossils, gathered by Prof. Henry Newton, whose untimely death science has reason to deplore. To this is to be added a series from Illinois, collected by Mr. George Spangler.

Numerous collections of minerals have been added to the museum; but, for the most part, necessarily stored with the other accumulations for the want of a proper opportunity of exhibition. The most important of these consists of a collection illustrating the iron and steel manufactures of Sweden. This constituted the exhibit of that government at

the exhibition at Vienna, in 1873. It was presented by the commissioner, Mr. Dannfeldt, to the Philadelphia Centennial Commission, but was not exhibited, having been stored in Philadelphia until the past summer, when it was presented by the Centennial Board of Finance to the United States.

This exhibit was quite equal in value to that displayed by Sweden at Philadelphia, and which became the property of the Institute of Mining Engineers. The collection, amounting to about fifteen tons in weight, was carefully packed under the supervision of Mr. Thomas Donaldson, and forwarded to the Institution.

Messrs. Dunn & Brothers, of Philadelphia, presented three boxes of China clay from an establishment in England, of which they are the agents.

Surveyors-General Wasson and Hardenburg have continued their contributions of specimens illustrating the character of the ores in newly-discovered mining regions in Arizona, &c. Mr. C. W. Derry presented a collection of silver ores from the J. D. Dana Mine in Colorado. Mr. Reynolds, the United States minister to Bolivia, has transmitted a series of copper ores of that country, and a large number of single specimens have been received, sent in for the purpose of identification.

It will be seen, from the preceding enumeration and from the list of donations, that the collections are of varying magnitude, some being exhaustive and covering all branches of natural history, others limited to a single department and sometimes to a single specimen. All these, however, find their place, a single object sometimes being more valuable than a large collection in supplying an important gap.

The most important sources of supply, as will be understood from what has already been said, have been the several government expeditions, particularly those of Lieutenant Wheeler and of Major Powell; the articles of general and natural history and ethnology obtained from these two officers being of very great magnitude and value.

The thanks of the Institution are due for 1877, as in previous years, to the Alaska Commercial Company, for disinterested and important services in acting as its agent in receiving and forwarding specimens and supplies transmitted between the Smithsonian Institution and its correspondents on or near the Pacific coast of North America and Asia; in giving free transportation on its vessels to their correspondents and their equipment and collections, as well as subsistence and quarters at its stations; in supplying objects of natural history, valuable in a scientific point of view as well as commercially; and in every possible way giving to the Smithsonian Institution the benefit of its organization and opportunities in the most liberal manner, and, in all cases, without any charge beyond that required for the reimbursement of moneys actually paid.

The United States Signal Service, under General Myer, has taken part, with its usual liberality, in the efforts of the Institution to in-

crease the knowledge of the natural history of North America, by allowing it to nominate observers at several of its Northwestern posts, who possessed the necessary interest and skill to make collections and observations. Noteworthy among these are Mr. Lucien M. Turner, for several years stationed at Saint Michaels, in Alaska, and his successor at that post, Mr. E. W. Nelson.

Single collections have been received from time to time from other observers in the service. Reference has been made to Dr. J. C. Merrill, of the United States Army, who made collections on the Lower Rio Grande, in the vicinity of Brownsville. This gentleman has enabled us in great measure to complete the work begun years ago by Dr. Berlandier, and continued by Lieut. D. N. Couch, Gen. Stewart Van Vliet, Mr. J. H. Clark, Mr. Arthur Schott, and other members of the Mexican Boundary Survey. Although but a short time resident at Fort Brown, Dr. Merrill has already made a great many important additions to the known fauna of that region. In this he has been aided by Mr. George B. Sennett, of Erie, Pa., who has also rendered valuable service to science.

To Mr. F. Hirst, of Bridger Station, Wyo., we owe many important contributions of birds, eggs, ethnological specimens, &c. Col. A. G. Brackett, U. S. A., also stationed in Wyoming, has likewise been a valued contributor.

Mr. Livingston Stone has added greatly to our knowledge of the fishes and ethnology of Oregon and California, by his collections in connection with the operations of the United States Fish Commission.

Lieutenant Wittich has also contributed toward the same end in Oregon. Mr. James G. Swan, for many years a collaborator of the Institution, and who, in 1875 and 1876, transmitted such extensive collections of ethnologica for the Centennial Exhibition of the Indian Bureau, has also made large contributions of various objects, during the year, from Puget Sound.

The sea-coast has been well explored by the United States Fish Commission on the coasts of Massachusetts and Nova Scotia, while the fishes of Narragansett Bay and vicinity have been investigated by Mr. Samuel Powel, of Newport.

The collections of birds and ethnologica from the National Museum of Mexico have been already adverted to, and relations have been established between the national museums of the two countries, which we hope will tend to their mutual benefit.

The residence of Mr. G. Brown Goode in Bermuda during the winter of 1876, has been productive of very desirable results; full series of the fishes, invertebrates, corals, &c., having been gathered.

The attention of the Smithsonian Institution has for many years been directed toward a thorough investigation of the natural history and ethnology of the West India Islands, and extensive explorations and collections have been effected through its agency in past years, in

the Bahamas, Jamaica, Cuba, Hayti, St. Domingo, Porto Rico, St. Thomas, Santa Cruz, and Antigua; thus covering very largely the western portions of the group, or the Greater and Lesser Antilles.

For the purpose of obtaining at least a general idea of the other islands more eastward, and of having them represented in the National Museum, the Smithsonian Institution, in the fall of 1876, made an engagement with Mr. Frederick A. Ober to proceed to that region, and, if possible, visit every island, large and small, occupying several years in the labor. The islands of Dominica, St. Vincent, Barbuda, Antigua, &c., have been explored by Mr. Ober up to the present date.

The subjects to which his attention was especially called were the archæology and ethnology of the islands, and their vertebrate animals. He has succeeded in finding remnants of the ancient Carib tribes, especially in Dominica, and has obtained numerous photographs of the people and specimens illustrative of their handiwork. His collections of birds have also been very extensive, embracing several undescribed species, and others of great rarity, or not previously represented in the National Museum.

Reference has been made, in previous reports, to the large collections made at the Kerguelen Islands by Dr. J. H. Kidder, while connected with the Transit of Venus Expedition. Some important deficiencies of specimens, however, not procurable during Dr. Kidder's visit, have been obtained, at his request, by Captain Fuller, of the merchant service, and presented to the Institution.

Scientific investigation of the collections.—As in previous years, the collections of the National Museum have been freely intrusted to competent naturalists for investigation and description; and much has been accomplished toward their proper classification and identification. Specimens of certain groups of mammals have been intrusted to Dr. Elliot Coues, of the United States Army, and Mr. J. A. Allen, of Cambridge, who are preparing a series of monographs for publication, under the direction of Dr. Hayden. A magnificent quarto by these two gentlemen, forming volume xi of the Reports of the Government Surveys of the Territories, and occupying 1100 pages, is devoted exclusively to the Rodentia, the materials derived almost entirely from the National Museum.

Other important monographs on the fur-bearing animals and on the insectivora have been likewise prepared by them.

The birds of America outside of the United States, and those of the West Indies, have been placed in the hands of Mr. George N. Lawrence who has published a number of papers upon them, describing several new species, principally from the collections of Mr. Ober and of Mr. Brace, of Nassau. Mr. Ridgway, the assistant in charge of the department of ornithology in the museum, has made investigations into the scientific relations of the raptores, the herons, &c., and published several monographs.

The reptiles have been placed in the hands of Prof. E. D. Cope for investigation.

The fishes have been elaborated by Prof. Theodore Gill, Mr. G. Brown Goode, Dr. T. H. Bean, and Professor Jordan. The latter gentleman has prepared some important monographs relating to the fresh-water fishes of the United States from the specimens of the National Museum, describing many new species.

Mr. William H. Dall has had charge of the Mollusca, and has described some new species. Others have been submitted to Mr. Thomas Bland.

The marine invertebrates collected by the United States Fish Commission are in the hands of Prof. A. E. Verrill, of Yale College, the special collaborator of the Commission. In their examination he has been assisted by Prof. Sidney I. Smith, of the same institution. Extensive monographs are in preparation by them, to be published by the Commission.

The sponges have been sent to Professor Hyatt, of Boston, our chief authority on that subject.

The fossil invertebrates have been investigated by Prof. C. A. White, the palæontologist of Dr. Hayden's survey.

In accordance with an arrangement of several years' standing, the collections of all vegetable substances, and of insects, have been transferred, as received, to the Department of Agriculture, and these have been properly elaborated by the officers in charge of the several departments of its museum.

The ethnological specimens have been studied carefully by Dr. Rau and Mr. Cushing, in charge of the department of the ethnological collection, Prof. O. T. Mason, and others. Professor Mason has published a paper, with numerous illustrations, upon the collections from Porto Rico, in the Smithsonian Report for 1876.

Work done in the museum.—The force in the museum occupied in the arrangement of the collections was necessarily diminished on account of the reduction of the Congressional appropriation, but all those retained have been diligently occupied in cataloguing the collections, in preparing and arranging them for exhibition, and in identifying and describing them.

As will be seen by a table in the appendix, the total number of entries of specimens during the year amounted to 11,398. Although this is not quite equal to the number recorded in 1876, it is considerably in excess of the receipts of any previous year.

The labor of receiving the specimens, ascertaining their exact origin, distributing them among the various departments, giving to them the treatment necessary for their permanent preservation, and finally their identification and entry, and deposit in a suitable place, is very great; no single day passing without some fresh addition of material requiring all these precautions. It is, however, believed that the National Museum will compare favorably with any establishment of its kind in the accomplishment of this necessary work with its actual force.

Distribution of duplicate specimens.—A very large portion of the labor during the year has been directed toward the selection and labeling, recording and packing, of duplicate specimens for distribution, in accordance with the act of Congress providing for the same.

In addition to a large number of single specimens or small series, supplied as the result of special application, a number of collections have been prepared embracing many extremely rare and desirable objects. Among the most important of these may be mentioned twenty-five sets of fishes, each containing seventy-five to one hundred and fifty species. These have been carefully identified and labeled, under the supervision of Professor Gill and Dr. Bean, and have constituted extremely acceptable additions to the museums to which they have been sent.

Other series of magnitude consist of birds' eggs, shells, bird-skins, &c.

A large number of series of diatomaceous earths have also been supplied, embracing forty or fifty different localities, many of them unknown to the investigator. The demand for them is very great, and taxes the ability of the person in charge to meet it.

Necessity of increased accommodations for the museum.—The necessity for more space has already been adverted to in the report for 1876, where full details will be found on the subject. It may be only necessary here to say that the exigency is greater than ever, in view of the largely-increased collections of the year and the deterioration caused to the animal and metallic specimens in consequence of their being boxed up and out of the reach of proper care. Very serious losses have already been experienced in the collections of wools, animal fibers, &c., and from the rusting of the specimens of iron and steel, and it is earnestly hoped that the next report may chronicle the initiation of measures by Congress for relief in this direction.

At present it is reasonable to estimate that the articles worthy of exhibition, but withdrawn from view, are several times greater in extent than those at present displayed, and that a correspondingly enlarged building is required for their display.

The collections thus withdrawn from exhibition consist not only of those most interesting to the naturalist, but also of such as are of the highest industrial value to the country, and will add greatly to the means of technical instruction, embracing as they do illustrations of different kinds of building-stone, ores of all kinds, earths, china and porcelain clays with the products derived from them, illustrations of the animal products of the country in the way of furs, oils, gelatines, glues, fibers, hair, bristles, chemical products, &c., and a great variety of articles to which reference is made in the report for 1876.

FISH CULTURE.

The labors of the United States Fish Commission, under Professor Baird's direction, have been prosecuted through the year with very satisfactory results.

As in previous years, the operations have been carried on under two distinct divisions: first, the inquiry into the condition of the American fisheries; and secondly, the multiplication of useful food-fishes in the rivers and lakes of the United States.

The first division embraces a critical examination into the physical and biological character of the waters, such as the determination of their temperature in different seasons, their currents, their chemical composition, the character of the bottom, and the precise nature of the animal and vegetable life occurring therein, with their mutual relations; as also the influences which may tend to affect the abundance and the distribution of the fish in different seasons, whether by natural causes, artificial impediments or obstructions, or by excessive fishing. Work in this direction has been conducted since 1871, and has resulted in supplying a minute and satisfactory knowledge of the character of the coast and off-shore portions of the United States, from the Bay of Fundy to Long Island Sound, and other portions of the sea-coast and of the lakes have been investigated in a less elaborate manner.

The operations in regard to the propagation of food-fishes relate especially to the introduction of California salmon, Atlantic salmon, land-locked salmon, and whitefish into new waters, or their multiplication in those that have been depleted. Special attention, also, in later years, has been directed to the European carp, a well known and favorite domesticated fish, and promising to be an important addition to the food resources of the United States.

The usual operations of the Fish Commission, in its maritime work during 1877, were somewhat modified by the attendance of Professor Baird on the International Fishery Convention on the part of Great Britain and the United States, at Halifax, by the request of the Secretary of State.

Under the law of Congress, which directs all needed aid to be furnished, as far as practicable, to the United States Fish Commission in its varied operations, by the executive departments of the government, the Secretary of the Navy has for several years supplied a steamer, completely equipped for use, and in the season of 1877 a much larger vessel than usual was detailed at the request of the Secretary of State; this was the tug Speedwell, an iron propeller of 310 tons and of great stanchness, and thoroughly fitted for her work. She was equipped for the special service at the navy-yard in Portsmouth, N. H., under the direction of Commodore Guest, and the scientific apparatus formerly used on board the United States steamer Blue Light was transferred to her at New London. She was commanded by Lieutenant-Commander A. G. Kellogg, with Dr. T. H. Sheets as surgeon, and Mr. A. V. Zane as engineer. The vessel reported for duty on the 31st of July, at Salem, at which point Professor Baird had been stationed for a month, engaged in the preliminary work of the commission prior to proceeding to Halifax. This consisted, in part, in the collection of statistical information

in regard to the present condition of the American fisheries, for which purpose circulars were printed and distributed very extensively along the coast, and several competent agents were detailed for making the necessary inquiries.

As in previous years, Prof. A. E. Verrill, of Yale College, assisted by Mr. E. B. Wilson, took special charge of the investigations in regard to the marine invertebrates, while Mr. G. Brown Goode and Dr. T. H. Bean discharged a similar relation to the vertebrates. A number of trips were made by the vessel from Salem, which resulted in the discovery of some new and extensive fishing-grounds of much value, which it is believed will in time be utilized in the interest of the American fisheries.

Professor Baird proceeded to Halifax about the middle of August, where he was joined by the Speedwell on the 22d, from which point a new series of researches was carried on tending to still further elucidate the fisheries of the United States and of the British possessions.

The opportunity furnished by the presence of many intelligent fishermen and other witnesses called on both sides by the convention, was embraced by Professor Baird to secure information in regard to the condition, extent, and location of the American fisheries and the details of their prosecution, and enabled him to collect material for an exhaustive work on the subject, to be published at some future time in the report of the commission.

Professor Baird's duties in Washington required his return from Halifax a short time before the close of the convention, and he left on the 20th of October for home, the steamer Speedwell having proceeded to Salem on the 13th; and, after remaining a few days and carrying on some investigations in regard to the habits and distribution of the sea-herring, she reported herself at Portsmouth and was taken out of commission.

The season of 1877 was unusually productive in the increase of our knowledge of the natural history of the coast; a number of species having been added to previous lists, a considerable proportion new to science.

The work of the commission in the direction of the propagation of food-fishes began in April with the shad, an establishment having been formed at Havre de Grace, in the Susquehanna, where 11,000,000 of young shad were hatched out and distributed throughout the United States. During this season an entirely new system of hatching shad, invented by Mr. T. B. Ferguson, fish commissioner of Maryland, was put into successful operation. In this the necessary motion required by the eggs is imparted by steam machinery, which causes a cylindrical vessel in which the eggs are placed to rise and fall in the water with a proper degree of velocity. In this way many practical difficulties in the hatching of shad in open bays and elsewhere are overcome.

The work of hatching shad at Havre de Grace was prosecuted with the assistance of Mr. Ferguson, while the shipment and distribution of

the young fish was directed by Mr. J. W. Milner, Assistant United States Fish Commissioner.

After completing operations at Havre de Grace, the commission, under Mr. Milner, transferred its operations to Holyoke, in Massachusetts, which resulted in about the average success.

The yield of eggs of the California salmon from the United States establishment situated on the McCloud River, in Northern California, was not so large as usual, in consequence of the interference with the upward run of the fish by some canning establishments on the Lower Sacramento. Between five and six millions of eggs, however, were secured and duly distributed. These were sent to all parts of the United States, as also to Canada, Australia, New Zealand, the Sandwich Islands, Germany, France, England, and the Netherlands.

Nothing was done during the year with the Atlantic salmon, although the establishment at Bucksport was kept in repair.

Unusual success was experienced in the collection of eggs of the landlocked salmon in the Grand Lake Stream in Eastern Maine, about two millions having been secured and distributed to fish commissioners and other parties in a large number of States. This work was prosecuted in co-operation with the fish commissioners of Massachusetts and Connecticut, who bore a share of the expense.

In the early part of the year Mr. Rudolph Hessel, an experienced fish culturist, was sent to Germany to obtain a supply of the German carp, and he brought back several hundred of the best varieties. These were placed temporarily in certain ponds in Druid Hill Park, Baltimore, under the care of Mr. T. B. Ferguson.

For the further treatment of these fish, and the multiplication of sufficient numbers to commence distributing them throughout the United States, Congress, in the latter part of the year, granted to the commission the use of the ponds on the Monument lot, in the city of Washington, and made an appropriation to fit them up properly. Work has been begun upon these ponds, and it is hoped that in the course of the year 1878 a successful beginning may be made in the way of distribution of fish from them.

The labors of the United States Fish Commission can scarcely be too highly estimated. A very large and increasing portion of human life is sustained by the product of the water, especially of shores and rivers. Organic matter necessary to the sustentation of life is produced by radiation from the sun in connection with plants, but a large portion of this is carried into the waters of rivers and that of the sea, by sewage and drainage, and can only be reclaimed for human use by the production of fishes. Hence, with the increase of population of civilized countries, the art of breeding and catching fish becomes as important, almost, as the extension of arable land and the improvement of agriculture. Indeed, it becomes in some respects more valuable than these, since it supplies food differing from that of the land; and, therefore, adds to the variety of the means for gratifying the palate.

The improvement which has been made in the art of producing fish is truly wonderful. Rivers, ponds, and lakes which are almost entirely barren or inhabited only by fish of but little value may be filled to repletion and kept full by judicious arrangement of the time of catching. The rules, however, for the art of fish culture are founded on scientific observations relative to the natural history of fish, and especially in regard to one principle, namely: that nature, to preserve a species, is prodigal in the production of individuals. This is especially true in regard to fishes; for example, from a single shad may be stripped 10,000 eggs which, being left exposed to all the enemies to which they are subjected, will yield not more than 50 young individuals able to feed themselves, and not more than 5 adult fish capable of reproduction, while the same number of eggs hatched by artificial means ought to yield 9,500 young fish, with a reasonable expectation of 950 adults.

The subject of fish culture has, however, but lately attracted the attention of the general government, the first small appropriation in regard to it having been made in 1872. It has, however, been extended year by year by small additional appropriations, and has now attracted such attention that the country will demand a still wider extension of its labors.

In this connection I would draw attention to the immense importance of the National Museum as an educational establishment. Specimens of every variety of fish in the different waters of the United States are sent by the employés of the Fish Commission to Washington in a fresh condition, and from them molds are immediately made in plaster from which again models are cast and painted to give exact representations in form and color of the original specimens. In this way in the course of a limited time a full set of all the edible fish of North America will be obtained, as well as models of those of a similar character from other countries. In addition to this, the National Museum has now in its possession ready for exhibition when a new building shall be provided, specimens of all the apparatus used in all the different countries of the world for the capture and utilization, as well as the propagation of fish.

The importance of such a collection as a means of diffusing and improving practical ideas can scarcely be too highly estimated.

CONCLUSION.

It will be seen from the report of Professor Baird that a large amount of his time has been expended in labor for the general government, in relation to American fisheries.

Almost from the first organization of the Institution until the present time the officers of the Institution have rendered service to the general government without additional salary. For several years past the Secretary has devoted the greater part of the summer to investigations on sound in its application to fog-signals, in connection with the Light-House Board.

These investigations have been made along the coast on light-house steamers, with the assistance of members and officers of the light-house establishment. During the last year a series of experiments were made along the coast of Maine, which served to establish some new principles, as well as to confirm previous results.

From all the experiments which have been made by the Light-House Board in regard to the transmission of sound in free air and those derived from other observations which can be fully relied upon, the following conclusions may be considered established, subject, however, to such further modification and extension as subsequent investigation may seem to indicate:

"1. The audibility of sound at a distance (the state of the atmosphere being constant) depends upon the character of the sound. The distance through which a sound may be heard is governed by the pitch, the loudness, and the quantity of sound. The pitch or frequency of the impulses in a given time must not be too high, otherwise the amplitude of vibration will be too small to allow a sufficient quantity of air to be put into motion; neither must the pitch be too low, for in this case the motion of the atoms of air in the sound-wave will not be sufficiently rapid to convey the impulse to a great distance. Again, the greater the loudness of the sound, which depends upon the amplitude of the vibrations of the sounding body, the greater will be the distance at which it will be heard. And finally, the greater the quantity of sound, which depends upon the magnitude of the vibrating surface, the greater will be the distance to which it is audibly transmitted. These results are derived from observations on the siren, the reed-trumpet, and the automatic buoy. The effect of quantity of sound is shown in the fact that in sounding different instruments at the same time, it was found that two sounds apparently of the same loudness were heard at very different distances. The audibility of sound depends upon the state of the atmosphere.

2. A condition most favorable to the transmission of sound is that of perfect stillness and uniform density and temperature throughout. This is shown by the observations of Parry and other Arctic explorers; although in this case an efficient and co-operating cause is doubtless the downward refraction of sound due to the greater coldness of the lower strata of air, as first pointed out by Professor Reynolds. Air, however, is seldom in a state of uniform density, but is pervaded by local currents, due to contact with portions of the earth unequally heated, and from the refractions and reflections to which the sound-wave is subjected in its passage through such a medium it is broken up and lost to the ear at a less distance.

3. But the most efficient cause of the loss of audibility is the direct effect produced by the wind. As a general rule, a sound is heard farther when moving with the wind than when moving against it. This effect, which is in conformity with ordinary observation, is not due to

an increase of velocity of the sound-wave in one direction and a diminution in the other by the motion of the wind except in an imperceptible degree; for since sound moves at the rate of about seven hundred and fifty miles an hour, a wind of seven miles and a half an hour could increase or diminish the velocity of the sound-wave only one per cent., while the effect observed is in some cases several hundred per cent. It is, however, due to a change in its direction. Sound moving with the wind is refracted or thrown down toward the earth; while moving against the wind it is refracted upward and passes over the head of the observer, so as to be heard at a distance at an elevation of several hundred feet when inaudible at the surface of the earth.

4. Although, as a general rule, the sound is heard farther when moving with the wind than when moving against it, yet in some instances the sound is heard farthest against the wind, but this phenomenon is shown to be due to a dominant upper wind, blowing at the time in an opposite direction to that at the surface of the earth. These winds are not imaginary productions invented to explain the phenomena, but actual existences, established by observation, as in the case of the experiments made at Sandy Hook in 1874, by means of balloons, and from the actual motion of the air in the case of northeast storms, as observed at stations on the coast of Maine.

5. Although sound issuing from the mouth of a trumpet is at first concentrated in a given direction, yet it tends to spread so rapidly, that at the distance of three or four miles it fills the whole space of air inclosed within the circuit of the horizon, and is heard behind the trumpet nearly as well as at an equal distance in front of its mouth. This fact precludes the use of concave reflectors as a means of increasing the intensity of sound in a given direction; for although at first they do give an increase of sound in the direction of the axis, it is only for a comparatively short distance.

6. It has been established, contrary to what has formerly been thought to be the case, that neither fog, snow, hail, nor rain materially interferes with the transmission of loud sounds. The siren has been heard at a greater distance during the prevalence of a dense and widely-extended fog than during any other condition of the atmosphere. This may, however, be attributed to the uniform density and stillness of the air at the time.

7. In some cases sound-shadows are produced by projecting portions of land or by buildings situated near the origin of the sound, but these are closed in by the spread of the sound-waves, and thus exhibit the phenomenon of sound being heard at a distance and afterwards lost on a nearer approach to the station.

8. It frequently happens that on a vessel leaving a station the sound is suddenly lost at a point in its course, and after remaining inaudible some time, is heard again at a greater distance, and is then gradually lost as the distance is farther increased. This phenomenon is only observed when the sound is moving against the wind, and is therefore

attributed to the upward refraction of the sound-wave, which passes over the head of the observer and continues an upward course until it nearly reaches the upper surface of the current of wind, when the refraction will be reversed and the sound sent downward to the earth; or the effect may be considered as due to a sound-shadow produced by refraction, which is gradually closed in at a distance by the lateral spread of the sound-wave near the earth, on either side, in a direction which is not affected by the upward refraction. Another explanation may be found in the probable circumstance of the lower sheet of sound-beams being actually refracted into a serpentine or undulating course, as suggested in the Appendix to the Report of the Light-House Board for 1875. Such a serpentine course would result from successive layers of unequal velocity in an opposing wind; as being retarded at and near the surface of the earth, attaining its maximum velocity at the height of a few hundred feet, and then being again retarded at greater elevations by the friction of upper counter-currents, or stationary air. In some cases the phenomenon is due to one or the other of these causes, and in other cases to both combined. That it is not due to the obstructing or screening effects of an abnormal condition of the atmosphere is shown by the fact that a sound transmitted in an opposite direction, through what is called the region of silence, passes without obstruction. It is probable, from all the observations, that in all cases of refraction of a sound moving against the wind, it tends again to descend to the earth by the natural spread of the sound.

9. The existence of a remarkable phenomenon has been established, which is exhibited in all states of the atmosphere during rain, snow, and dense fog, to which has been given the name of aerial echo. It consists of a distinct echo, apparently from a space near the horizon of fifteen or twenty degrees in azimuth, directly in the prolongation of the axis of the trumpet. The loudness of this echo depends upon the loudness and quantity of the original sound, and therefore it is produced with the greatest distinctness by the siren. It cannot be due to the accidental position of a flocculent portion of atmosphere nor the direct reflection from the crests of the waves, as was at first supposed, since it is always heard except when the wind is blowing a hurricane.

As a provisional explanation, the hypothesis has been adopted that in the natural spread of the waves of sound some of the rays must take such a curvilinear course as to strike the surface of the water in an opposite direction and thus be reflected back to the station or location of the origin of the sound."

Respectfully submitted.

JOSEPH HENRY,
Secretary Smithsonian Institution.

WASHINGTON, *January*, 1878.

APPENDIX TO THE REPORT OF THE SECRETARY.

GOVERNMENT EXPLORATIONS IN 1877.

In accordance with the law of organization of the Institution, all the specimens that are brought to Washington by the various government surveys and expeditions are turned over to the National Museum in charge of the Smithsonian Institution, and, therefore, accounts are here given of the Government explorations during the past year under the direction of Professor Hayden, Professor Powell, and Lieutenant Wheeler, furnished by the directors of the explorations.

THE WORK OF THE UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES, UNDER THE DIRECTION OF PROF. F. V. HAYDEN, DURING THE SEASON OF 1877.

On the completion of the work in Colorado in 1876, it was determined that the work should continue northward into Idaho and Wyoming Territories. The belt of country along the fortieth parallel, including the Union Pacific Railroad, having been explored in detail by the survey of the fortieth parallel under Clarence King, it was deemed best to commence at the northern boundary of that work and continue northward and westward.

The survey was divided into five parties for field, geological, and topographical work, besides several parties for special investigation. The following notes present the salient features of the summer's work:

Primary triangulation.—The primary triangulation party in charge of Mr. A. D. Wilson, chief topographer of the survey, took the field from Rawlins Springs, Wyo. Near this place a base-line was carefully measured and from this a net-work of triangles was extended to the north and west. After completing the work in the vicinity of Rawlins, the party marched northward, making stations on Seminoe and Whiskey Peaks, and thence traveled westward to Yellow Butte, where another station was located. From this point the work was carried to the Wind River Range. Three stations were made on the more prominent points of this range with much difficulty, owing to the great quantities of snow found in these mountains during the month of June—the time the party was working there.

Continuing the work northward and westward, stations were made on the Grosventre and Wyoming Ranges and on Caribou Mountain and Mount Putnam near Fort Hall. After refitting at the latter place the party marched south via Soda Springs to the valley of Bear Lake, where another base-line was measured and connected with the work as brought forward from the Rawlins base.

After occupying Mount Preuss, Soda, Paris, and North Logan Peaks, the party marched to Evanston where a connection was made with the

astronomical station made at this point by the boundary survey of Wyoming. Stations were also made on Medicine Butte and Ogden Peak, thus connecting with the primary triangulation of the fortieth parallel survey. From Evanston the party moved eastward, occupying Pilot and Black Buttes, again visiting Separation Peak near Rawlins, thus bringing the work back to the point of beginning where the party was disbanded and the train sent into winter quarters at Cheyenne.

Mr. Wilson has finished the preliminary computations of his work, and a chart, showing the results, has been published. Twenty-six points were occupied, while many others were located by foresights, among them the Grand Téton and Washakie Needles.

The triangulation covered an area of about 28,000 square miles, extending from longitude 107° to 112° and between north latitude 41° 10′ and 43° 50′.

Stone monuments were built on all occupied points for future reference, and when the final computations are made, the latitude and longitude of all these points will be given, with azimuths and distances between the points.

Topography.—The topographical field-work of the past season was carried on by three parties, to each of which a definite area was assigned to be surveyed. These areas were approximately in the form of rectangles, limited by meridians and parallels of latitude. Each of them contained about 11,000 square miles. That assigned to the Teton division, in charge of Mr. G. R. Bechler, lay between the meridians of 109° 30′ and 112° and the parallels 43° and 44° 15′. This area comprises nearly all the country about the sources of Snake River, including the very rugged range of the Teton Mountains and the northern half of the Wind River Mountains. From the character of the country, being nearly all mountainous, and much obstructed by living and fallen timber, work was necessarily slow, yet Mr. Bechler succeeded in surveying nearly 6,000 square miles up to the early part of September, when he was obliged to stop work and leave the country, owing to the proximity of Joseph's band of hostile Indians. About one-third of the area surveyed by this division lies south of the Snake and west of Salt River. The remainder includes the greater part of the most rugged mountains, among them the Tetons and a portion of the Wind River Range.

That portion of the district lying south of Snake River consists of the northern ends of two mountain-ranges, known as the Blackfoot and Caribou ranges, with their adjacent valleys. These ranges have the normal trend; are here scarcely high enough (6,000 to 8,000 feet above sea-level) to be dignified with the name of mountains, and are bare of timber and grass-covered. All this section is fine grazing-land, and in the valleys are large areas of arable land.

North of the Snake are several fine valleys, well watered from the snow-fields of the high mountains, among which are Pierre's and Jackson's Holes; but the mass of the country is made up of mountains.

As a rule, the valleys are narrow, mere cañons in very many cases. The mountains are everywhere heavily timbered with pine and spruce.

During the season, Mr. Bechler occupied 60 stations, and measured 7,340 horizontal and 5,700 vertical angles.

The area assigned to the Green River division, in charge of Mr. Henry Gannett, lay between the meridians of 109° 30′ and 112° 00′ and the parallels of latitude of 41° 45′ and 43° 00′, being directly south of that of the Teton division. This district includes the northern half of the Green River Basin; nearly all the drainage area of the Bear, and several large branches of the Snake, comprising portions of the three Territories Wyoming, Idaho, and Utah. The country being especially well adapted to this class of surveying, work was pushed very rapidly, so that, after finishing his district, Mr. Gannett was enabled to carry the work westward over the valleys of the Portneuf and Malade, with their bounding ranges.

With the exception of the Green River Basin, which is a broad, flat expanse of sage and grass, the country consists of a succession of parallel ranges of mountains, with the normal Rocky Mountain trend, separated by broad valleys. The valleys are fertile, and easily irrigated, while everywhere there is a bountiful supply of water. The average elevation of these valleys is from 4,000 to 6,000 feet, while the mountains rise to heights ranging from 8,000 to 11,000 feet.

The lower mountain-ranges are grass-covered, while the higher ones are well timbered, in some cases even densely timbered, with heavy spruce and pine. The area of irrigable land is, by a rough estimate, ten per cent. of the district, while at least three-fourths of it is suitable for grazing. In surveying this area, Mr. Gannett made 347 stations of all grades of importance, building monuments on 53 of the principal ones for future reference by the land surveys, or other purposes.

The district assigned to the Sweetwater division, under Mr. George B. Chittenden, lay between meridians 107° 00′ and 109° 30′ and parallels 41° 45′ and 43° 00′, being east of that last described. It includes the southern half of the Wind River Range, the valleys of Wind River and the Sweetwater, with the Sweetwater Mountains and the desert-like plateaus about the continental divide south of the latter. Of this area nearly all or between 10,000 and 11,000 square miles were surveyed. Of this district, a rough estimate makes five-eighths desert country, two eighths mountainous, of value only for its timber, or, hypothetically, for its mineral contents, and one-eighth only valuable as pasture or agricultural land. In surveying this area, Mr. Chittenden made nearly 200 stations. Between 80 and 90 of these were marked permanently by stone monuments for future reference.

As heretofore, attention has been paid to the economic value of the land surveyed. Map notes and sketches indicate the extent of land suitably situated for irrigation, and as all streams of any magnitude are gauged, and their slopes measured, the data for estimates of the amount

of arable land are at hand. Areas of pasture and timber land are also noted.

During the whole season, of four months' duration, the weather was unexceptionably favorable for the prosecution of the work; scarcely a day was lost from bad weather by any of the parties.

The total area surveyed during the season, and to be mapped during the winter, was about 29,000 square miles, a very considerable addition to our knowledge of the Western country.

In succeeding years the work is to be extended toward the north, east, and west.

Geology.—The geological field-work of the survey for 1877 was assigned to Dr. F. M. Endlich, Prof. Orestes H. St. John, and Dr. A. C. Peale, in the Sweetwater, Teton, and Green River districts respectively. Many interesting geological facts were observed which will be detailed in the annual report of the survey.

The Sweetwater district comprised a well diversified country. The eastern portion of the Green River Basin was found to be underlaid with Tertiary formations, with isolated volcanic eruptions at several points. The prevailing westerly winds of the region have resulted in the formation of sand dunes wherever the configuration of the country has offered an obstacle to the progress of the sand that is formed from the readily disintegrating Tertiary sandstones. On the eastern side of the Wind River Mountains a full series of the sedimentary formations was noted, beginning with the Silurian, and numerous stratigraphical phenomena were observed and studied with a view to the determination of the age of the mountain-range.

Camp Stambaugh, at the south end of the range, is located within the area of the oldest metamorphic rocks of the district In these, gold has been found in varying quantities for the last ten years, and, at one time, the region was the scene of considerable mining excitement.

The western side of the Wind River Mountains was found to be very interesting on account of the remains of enormous ancient glaciers. Moraines, covering many square miles, and often a thousand feet in thickness, extend downward through narrow valleys that now contain rushing streams. Striation, grooving, and mirror-like polish of rock *in situ*, denote the course taken by the moving ice-fields that have left these marks of their former existence. From all indications, the cessation of glacial activity must have occurred within a comparatively recent time. Scarcely any vegetation has sprung up on the light glacial soil, and the characteristic distribution of erratic material bears every evidence of "freshness."

All along the Sweetwater River the characteristic Sweetwater group of the Tertiary was found, continuing northward to the hills opposite Seminoe Pass. These hills were found to be projections of granite that during the Tertiary epoch, and probably long before, existed as islands in a widely extended sea.

On the south side of the Sweetwater, in the Seminoe Hills, the older

sedimentary formations were noted. In the region between the Seminoe Hills and Rawlins, on the Union Pacific Railroad, an interesting group of mud-springs, analogous to the mud-puffs of the Geyser region, were seen. About four hundred of these curious springs were found and examined.

After finishing his work with the field-party, Dr. Endlich visited the coal-mines near Evanston, Wyo., to examine the coal-bearing rocks of that region.

The Green River district lies directly west of the Sweetwater district. With the exception of a small area of granite, along the southwestern side of the Wind River Mountains, and some basaltic flows in the northwestern portion of the district, the rocks are sedimentary. The Green River Basin was the first area surveyed. The prevailing formation was found to be the Green River group of the Tertiary, underlaid by the Wahsatch. Toward the south, buttes of the Bridger clays rest on the Green River marls and sandstones. They are the northern outliers of the extensive Bridger areas found farther southward.

On the northeast, the Tertiary beds rest on the granites of the Wind River Mountains, the line of junction being considerably obscured by morainal material. One of the most interesting points noted in the Green River Basin was on its west side, where the Wahsatch Tertiary is seen resting unconformably on Jurassic and Cretaceous strata. At one point, Carboniferous fossils were obtained from bowlders of limestone found in a conglomerate in the Wahsatch group. These were derived without doubt from the Carboniferous limestones of the mountains that stand a short distance to the westward, and which must once have formed a portion of the shore-line of the lake filling the Green River Basin.

An arm of this Tertiary lake extended up Harris Fork of the Green River, where Green River and Wahsatch beds are found in horizontal position. In the Green River shales, at several localities, good collections of fossil fish and insects were found, among which were many new species.

The region of the Blackfoot River, in the northwestern part of the district, is covered in all its lowest portions with flows of basalt which had their origin in craters that still show between the Blackfoot, Bear, and Portneuf Rivers. The pouring out of this basalt must have occurred either during or just prior to the present period, as there has been but little if any change in the surface since the eruption. On the Portneuf River a narrow tongue of basalt extends almost to Snake River Valley. The surface of this basalt slopes somewhat, but not so much as the present bed of the Portneuf. The lower valley of the Portneuf is interesting from the fact that it is probably one of the ancient outlets of the great lake that once filled the Salt Lake Basin and extended across into Cache Valley. In Cache Valley and Malade Valley, modern Tertiary deposits are found jutting against the mountains, and in the central por-

tions of the valleys they seem to pass gradually into the more modern deposits.

The interesting soda-springs at the bend of Bear River were carefully examined.

Although the area surveyed by the Green River division was large, comprising about 13,000 square miles, large collections of fossils (many of them new) were made. Notes were obtained for the preparation of a geological map of the area, and data collected for the elucidation of many interesting problems in relation to the age of the mountains.

Coal-outcrops were noted at a number of localities, on some of the branches of the Upper Bear River and of Green River. The famous salt-works on a branch of Salt River were also examined.

Professor St. John reports the Teton district to be one of great interest. He found extensive areas covered with rocks of igneous origin, basalts, and trachytes.

The Snake River plains are everywhere floored with basaltic rocks. They extend up the valley of the Snake as far as the lower basin, where they are succeeded by other volcanics, mainly trachytes. The latter are observed inclining at greater or less angles and appear to be more ancient than the basalts. The Blackfoot Valley and the valley depressions between the Blackfoot Mountains and the Caribou Range are floored with basalts in every way similar to those occurring in the Snake River plains. These extend southward into Dr. Peale's district.

Rhyolitic products were found at a few localities. In one instance the eruptive matter appears as a dike in the crest of a low, short ridge between the Blackfoot and Caribou Ranges, its eruption having tilted the sedimentary deposits into an anticlinal ridge.

In Caribou Mountain, also, interesting phenomena were observed. The mountain is a monoclinal ridge, made up of sedimentaries, between whose strata the igneous material is intruded, appearing from a distance like veritable beds of deposition, while the bulk of the west portion of the mountain appears to consist of an enormous mass of eruptive matter thrust up from below. This mountain would therefore appear to be another instance of local outburst, similar to those brought to light by the survey in Western and Southwestern Colorado.

Extensive areas of the district are occupied by sedimentary or stratified rocks, which were referred to the Lower Silurian, Carboniferous, Jura-Triassic, Cretaceous, and Tertiary ages. These rocks have been subjected to considerable folding and displacements in the different portions of the district.

One of the most interesting discoveries was that of the presence of fish-remains in the Lower Carboniferous. Several forms were found, identical with or closely allied to Keokuk species of the genera *Cladodus*, *Petalodus*, *Anthiodus*, and *Helodus*.

In the upper basin of Snake River, Tertiary lacustrine beds occur. These are probably the equivalents of the lake-beds of Dr. Hayden.

The Teton Range was examined and found to be a gigantic monoclinal

ridge, with a metamorphic and granitic nucleus, which forms a lofty, exceedingly rugged, jagged crest, extending in a north and south direction three-fourths the length of the range, culminating in Mount Hayden.

In Jackson's Basin, east of the Teton Range, a vast accumulation of morainal matter was noted. Along the west side of the basin, extensive morainal accumulations occur, which have been cut into beautiful terraces by Snake River.

Calcareous tufa, indicating the presence of springs, was found at the mouth of Salt River, in a small basin east of Lincoln Valley, &c. None of these, however, are comparable with the enormous spring deposits met with at the northeastern foot of the Wind River Mountains, in the upper portion of the Wind River Valley, which were hastily examined late in the season.

The geological notes given above present only the salient features of the season's work.

Paleontology.—During the past year the prosecution of paleontological investigation in the field has constituted a prominent feature of the work. This investigation embraces not only a collection and study of the fossil remains, but also the application of such study to the correlation of the geological formations that occupy the different districts that have from year to year been surveyed by various parties. Dr. C. A. White, the paleontologist of the survey, has been placed in chage of this branch of the work, which he pursued in the field during the whole of last season. The region studied by him is briefly as follows: That portion of the great plain which lies adjacent to the east base of the Rocky Mountains between Cheyenne and a point 25 or 30 miles south of Denver; a portion of Middle Park; the district drained by Yampa and White Rivers into the Green; the district which lies adjacent to the southern base of the Uinta range of mountains; that which lies adjacent to the northern side of those mountains; a large part of the Green River Basin, and eastward as far as Rawlins Station on the Union Pacific Railroad.

The results have been very gratifying; among the more important of which is the definition of the paleontological boundaries of certain of the groups of strata, especially those of the Laramie group, over a large area, including both sides of the Rocky Mountains. He has demonstrated the fact that at least the lower portion of the Fort Union group, the Lignitic group of Colorado east of the Rocky Mountains, and the Laramie group of King west of those mountains, including the great Bitter Creek series of beds, all belong to one period, and which are included under the general name of Laramie group.

In the valley of Lake Fork south of the Uinta Mountains, he found the Bridger group well exposed, and in the valley of the Du Chesne, the Green River group. Both these groups have there the peculiar lithological characteristics that distinguish them in the Green River Basin north of the Uintas.

Important collections of fossils were made by Dr. White, comprising

many new forms, and also many interesting types. Some important data were also obtained, showing the early differentiation and extraordinary persistence of fresh-water and land molluscan types. A discussion of these and other kindred questions will appear in his paleontological reports.

Fossil entomology.—Messrs. S. H. Scudder, of Cambridge, and F. C. Bowditch, of Boston, spent two months in Colorado, Wyoming, and Utah, in explorations for fossil insects, and in collecting recent Coleoptera and Orthoptera, especially in the higher regions. They made large collections of recent insects at different points along the railways from Pueblo to Cheyenne and from Cheyenne to Salt Lake, as well as at Lakin, Kans., Garland and Georgetown, Colo., and in various parts of the South Park and surrounding region.

For want of time, they were obliged to forego an anticipated trip to White River, to explore the beds of fossil insects known to exist there. Ten days were spent at Green River and vicinity in examining the Tertiary strata for fossil insects, with but poor results; the Tertiary beds of the South Park yielded but a single determinable insect, but near Florissant the Tertiary basin, described by Dr. A. C. Peale in the annual report of the survey for 1873, was found to be exceedingly rich in insects and plants.

In company with Rev. Mr. Lakes, of Golden, Mr. Scudder spent several days in a careful survey of this basin, and estimates the insect-bearing shales to have an extent at least fifty times as great as those of the famous locality at Oeningen in Southern Bavaria. From six to seven thousand insects and two or three thousand plants have already been received from Florissant, and as many more will be received before the close of the year.

Mr. Scudder was also able to make arrangements in person with parties who have found a new and very interesting locality of Tertiary strata in Wyoming, to send him all the specimens they work out, and he confidently anticipates receiving several thousand insects from them in the course of the coming winter. The specimens from this locality are remarkable for their beauty. There is, therefore, every reason to believe the Tertiary strata of the Rocky Mountain region are richer in remains of fossil insects than any other country in the world, and that within a few months the material at hand for the elaboration of the work on fossil insects, which Mr. Scudder has in preparation for the survey, will be much larger than was ever before subject to the investigation of a single naturalist.

Fossil botany.—Prof. Leo Lesquereux has been engaged during the past year in studies of the tertiary flora. These are now completed, and his monograph has been issued from the press.

Botany.—The botany of the Survey was represented the past season by the two great masters of that department, Sir Joseph D. Hooker, director of the Kew Gardens, England, and president of the Royal Society of London; and Prof. Asa Gray, of Cambridge, Mass. Their

examinations extended over a great portion of Colorado, Wyoming, Utah, Nevada, and California. Their investigation into the Alpine floras and tree-vegetation of the Rocky Mountains and Sierra Nevada enabled them to give a clear idea of the relations and influence of the climatic conditions on both sides of the great mountain-ranges.

Sir Joseph Hooker, whose botanical researches embrace the greater part of Europe; the Indies, from the Bay of Bengal across the Himalaya's to Thibet; the antarctic regions and the southern part of South America, New Zealand, Australia, South Africa, Morocco, and Asia Minor, presents in the English periodical "Nature," for October 25, 1877, an outline of his studies during the season, and this outline, when filled out, will form a most important part of the eleventh annual Report of the Survey. It will be seen at a glance that the report will be of the most comprehensive character, and cannot fail to be of the highest interest to our people. The tree-vegetation, and especially the coniferæ, were made special objects of study, and many obscure points were cleared up.

Dr. Hooker sums up the results of the joint investigations of Dr. Gray and himself, aided by Dr. Gray's previously-intimate knowledge of the elements of the American flora, from the Mississippi to the Pacific coast:

That the vegetation of the middle latitudes of the continent resolves itself into three principal meridional floras, incomparably more diverse than those presented by any similar meridians in the Old World, being, in fact, as far as the trees, shrubs, and many genera of herbaceous plants are concerned, absolutely distinct. These are the two humid and the dry intermediate regions above indicated.

Each of these, again, is subdivisible into three, as follows:

1. The Atlantic slope plus Mississippi region, subdivisible into (α) an Atlantic, (β) a Mississippi Valley, and (γ) an interposed mountain region with a temperate and subalpine flora.

2. The Pacific slope, subdivisible into (α) a very humid, cool, forest-clad coast range; (β) the great, hot, drier Californian valley formed by the San Juan River flowing to the north and the Sacramento River flowing to the south, both into the Bay of San Francisco; and (γ) the Sierra Nevada flora, temperate, subalpine, and Alpine.

3. The Rocky Mountain region (in its widest sense extending from the Mississippi beyond its forest region to the Sierra Nevada), subdivisible into (α) a prairie flora, (β) a desert or a saline flora, (γ) a Rocky Mountain proper flora, temperate, subalpine, and Alpine.

As above stated, the difference between the floras of the first and second of these regions is specifically, and to a great extent generically, absolute; not a pine or oak, maple, elm, plane, or birch of Eastern America extends to Western America; and genera of thirty to fifty species are confined to each. The Rocky Mountain region again, though abundantly distinct from both, has a few elements of the eastern region and still more of the western.

Many interesting facts connected with the origin and distribution of American plants, and the introduction of the various types into three regions, presented themselves to our observations or our minds during our wanderings. Many of these are suggestive of comparative study with the admirable results of Heer's and Lesquereux's investigations into the Pliocene and Miocene plants of the north temperate and frigid zones, and which had already engaged Dr. Gray's attention, as may be found in his various publications. No less interesting are the traces of the influence of a glacial and a warmer period in directing the course of migration of arctic forms southward and Mexican forms northward in the continent, and of the effects of the great body of

water that occupied the whole saline region during (as it would appear) a glacial period.

Lastly, curious information was obtained respecting the ages of not only the big trees of California, but of equally aged pines and junipers, which are proofs of that duration of existing conditions of climate for which evidence has hitherto been sought rather among fossil than among living organisms.

Zoology.—Prof. Joseph Leidy, the eminent comparative anatomist and microscopist, made his second visit to the West the past season under the auspices of the Survey. He made a careful exploration of the country about Fort Bridger, Uinta Mountains, and the Salt Lake Basin, in search of rhizopods. He has been engaged for a long time on a memoir on this subject, which will eventually form one of the series of the quarto Reports of the Survey.

The rhizopods are the lowest and simplest forms of animals, mostly minute, and requiring high power of the microscope to distinguish their structure. While most of them construct shells of great beauty and variety, their soft part consists of a jelly-like substance. This the animal has the power of extending in threads or finger-like processes, which are used as organs of locomotion and prehension, often branching. From the appearance of their temporary organs, resembling roots, the class of animals has received its name of rhizopoda, meaning literally root-footed.

In compensation for the smallness of these creatures, they make up in numbers, and it is questionable whether any other class of animals exceeds them in importance in the economy of nature. Geological evidence shows that they were the starting-point of animal life in time, and their agency in rock-making has not been exceeded by later higher and more visible forms.

With the marine kind, known as foraminifera, we have been longest familiar. Their beautiful many-chambered shells—for the most part just visible to the naked eye—form a large portion of the ocean-mud and the sands of the ocean-shore. Shells of foraminifera likewise form the basis of miles of strata of limestone, such as the chalk of England and the limestones of which Paris and the pyramids of Egypt are built.

Fresh-water rhizopods, though not so abundant as marine forms, are nevertheless very numerous. They mainly inhabit our lakes, ponds, and standing waters, but they also swarm in sphagnous swamps and ever live in newest earth. Professor Leidy has devoted several years of study to the fresh-water rhizopods of the eastern portion of our country, and his especial object in the past expedition was to investigate those which are to be found in the elevated regions of the Rocky Mountains.

Dr. Elliott Coues, secretary and naturalist of the Survey, though prevented from taking the field during 1877 by the press of publications, which required his stay at the Washington office, has continued his investigations in Mammalogy and Ornithology. The printing of the "Birds of the Colorado Basin" has steadily progressed during the year, and very great accessions of material for his forthcoming Report on North Ameri-

can Mammalogy have been received. He is at present investigating the Insectivora of North America, with a view to a special monograph on that subject.

Mr. J. A. Allen is engaged upon an exhaustive memoir on the Pinnipeds, to be probably completed this year.

Dr. Coues reports unusual activity in the department under his charge, and a very forward state of the several investigations now in progress.

Archæology.—Mr. W. H. Jackson, photographer of the Survey, has added to his department the work of reproducing the ancient ruins of Southwestern Colorado, &c., by models. Specimens of the ancient pottery are also represented, not only by photographs, but also by actual models.

In the spring of 1877, Mr. Jackson made a tour over much of the northern part of New Mexico and westward to the Moqui towns in Arizona, and secured materials for a number of very interesting models, illustrating the methods of the pueblos, or town-builders, in the construction of their dwellings. Two villages have been selected for immediate construction, as showing the most ancient and best-known examples of their peculiar architecture, viz, Taos and Acoma; the one of many-storied, terraced houses, and the other built high upon an impregnable rock. The model of Taos is now completed, the dimensions of which are 42 by 39 inches, and the scale one inch to twenty feet, 1:240.

Of this town Davis says:

> It is the best sample of the ancient mode of building. Here are two large houses three or four hundred feet in length and about one hundred and fifty feet wide at the base. They are situated upon opposite sides of a small creek, and in ancient times are said to have been connected by a bridge. They are five and six stories high, each story receding from the one below it, and thus forming a structure terraced from top to bottom. Each story is divided into numerous little compartments, the outer tier of rooms being lighted by small windows in the sides, while those in the interior of the building are dark, and are principally used as store-rooms. * * * The only means of entrance is through a trap-door in the roof, and you ascend from story to story by means of ladders on the outside, which are drawn up at night.

Their contact with Europeans has modified somewhat their ancient style of buildings, principally in substituting door-ways in the walls of their houses for those in the roof. Their modern buildings are rarely over two stories in height, and are not distinguishable from those of their Mexican neighbors. The village is surrounded by an adobe wall, which is first included within the limits of the model, and incloses an area of eleven or twelve acres in extent. Within this limit are four of their *estufas*, or secret council-houses. These are circular underground apartments, with a narrow opening in the roof, surrounded by a palisade; ladders being used to go in and out.

These models are first carefully built up in clay, in which material all the detail is readily secured, and then cast in plaster, a mold being secured by which they are readily multiplied to any extent. They are then put into the hands of the artists and carefully colored in solid oil paints to accurately resemble their appearance in nature, and, in the case of restorations of modern buildings, all the little additions are made

which will give them the appearance of occupation. The Survey is in possession of the data for the construction of many more models, and they will be brought out as opportunity is given. They have also, in connection with the views, multiplied many of the curious pieces of pottery which have been brought back from that region by the various parties connected with the Survey.

Office work in 1877.—The early part of the year in the office was devoted to the completion of the Colorado work, and the latter part was occupied in working up the summer's notes.

During the summer, Mr. W. H. Holmes remained in the office, superintending the publication of the Atlas of Colorado, which is now rapidly approaching completion. A large portion of the time was devoted by him to the preparation of the "Economic Map," the "General Geological Map," the "Geological Sections," and the "Panoramic Views." The following are the sheets included in the Atlas of Colorado:

I. Triangulation Map.
II. General Drainage Map.
III. Economic Map.
IV. General Geological Map.

V. Northwestern Colorado.
VI. Northern Central Colorado.
VII. Central Colorado.
VIII. Western Colorado.
IX. Southwestern Colorado.
X. Southern Central Colorado.

XI. Northwestern Colorado.
XII. Northern Central Colorado.
XIII. Central Colorado.
XIV. Western Colorado.
XV. Southwestern Colorado.
XVI. Southern Central Colorado.

XVII & XVIII. Geological Sections.
XIX & XX. Panoramic Views.

Publications.—The year 1877 witnessed a marked increase in the number of publications of the Survey, no fewer than nine separate and formal works having been issued. These are enumerated as follows:

1. Catalogue of the publications of the Survey (second edition, revised to December 31, 1876).

2. The annual report for 1875, a large octavo of over 800 pages, fully illustrated with plates, maps, and wood-cuts, giving the results of the field-work of the year 1875, with an extensive appendix, consisting of J. A. Allen's Memoir on the Buffalo, and A. S. Packard's Report on Noxious and Beneficial Insects.

3. A preliminary report of progress for the field-season of 1877, forming part of the annual report of the Secretary of the Interior for 1877. The full reports for the years 1876 and 1877 are in press, and will form two large octavo volumes.

4. Volume III of the "Bulletin" of the Survey, containing very numerous articles in various departments of physical and biological science.

5. The fourth edition of miscellaneous publications No. 1, being "Lists

of Elevations," &c., by Henry Gannett, entirely revised and greatly enlarged, now forming an independent octavo volume of 167 pages.

6. Miscellaneous publications No. 7, "Ethnography and Philology of the Hidatsa Indians," by Dr. Washington Matthews, U. S. A.

7. Miscellaneous publications No. 8, "Fur-bearing Animals: a monograph of North American Mustelidæ," by Dr. Elliott Coues, U. S. A.

8. Miscellaneous publications No. 9, "Descriptive Catalogue of Photographs of North American Indians," by W. H. Jackson.

9. Eleventh volume of Final Reports, quarto series, "Monograph of North American Rodentia," by Dr. Elliott Coues, U. S. A., and Prof. J. A. Allen, forming a large quarto volume of 1110 pages, with plates.

Various publications, including Leo Lesquereux's Tertiary Flora, to form Volume VII of the quarto series, several numbers of the Bulletin, miscellaneous publications, and two annual reports are now in press.

GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION, BY PROF. J. W. POWELL, IN 1877.

About the middle of May last, the surveying corps again took the field. This year the rendezvous camp was at Mount Pleasant, a little town in Utah, about 125 miles south of Salt Lake City. Three parties were organized, under the direction of Prof. A. H. Thompson; one to extend the triangulation, and two for topographic purposes, the latter being under charge of Mr. W. H. Graves and Mr. J. H. Renshawe, respectively, and the former under the immediate direction of Professor Thompson, assisted by Mr. O. D. Wheeler.

The area designated for the season's work lies between 38° and 40° 30′ north latitude, and between 109° 30′ and 112° west longitude, Greenwich, and is embraced in atlas sheets 86 and 75.

Triangulation.—The triangulation party left Mount Pleasant in June. The work of this year being a continuation of the expansion from the Gunnison base-line, measured in 1874, it was desirable to first visit some of the geodetic points established in previous years, but the unprecedented amount of snow yet remaining in the high plateaus and mountains rendered this impracticable, and the first part of the season was spent in establishing stations on the Ta-vá-puts Plateau west of the Green River. In midsummer the party was able to visit the high plateaus and connect the work of past years with that of this season. Later the triangulation was extended to the east, joining the work of the United States Geological and Georaphical Survey of the Territories, under charge of Dr. F. V. Hayden, and to the north to join the work of the United States Geological Exploration of the Fortieth Parallel, Clarence King, United States geologist, in charge. The whole area of the season's work embraces something more than 13,000 square miles. The instrument used was the theodolite, hereafter described. The points sighted to on the geodetic stations were either artificial monuments or well-defined natural points, and all stations were marked by stone cairns.

Topographic work by Mr. Graves.—The district assigned to Mr. Graves

for topographic work was that embraced in the eastern half of atlas sheet 75, and that portion of sheet 86 lying east of the Green and Colorado Rivers, an area of about 10,000 square miles. The most remarkable topographic feature of this region is a bold escarpment facing the south, and extending from the western, far beyond the eastern limit of Mr. Graves' work. This is known as the Book Cliffs. At the foot of this escarpment lies a narrow valley, through which passes the only practicable route of travel between Central Utah and Western Colorado. South of the valley the whole region is cut by a labyrinth of cañons, formed by the Grand, Green, and San Rafael Rivers and their tributaries. This region is one of the most inhospitable and inaccessible in the territory of the United States. It is characterized by extreme aridity, and some portions are cut by many narrow gorges, forming "alcove lands." In other portions are found hills of naked sands and clays, regions of bad lands, bold cliffs, towering monuments, hills of drifting, glittering sands, and deep, tortuous cañons, which give to the landscape a strange and weird appearance.

The Book Cliffs rise to an average altitude above their base of 3,000 feet, and about 8,500 feet above the sea-level, and the country from the southern crest inclines gently northward to the valleys of the White and Uinta Rivers. This gigantic terrace, called the Ta-vá-puts Plateau, is cut in twain from north to south by the profound gorges through which the Green River runs, known as the Cañon of Desolation and Gray Cañon. The drainage of the plateau is northward from the brink of the cliffs through deep, narrow cañons for many miles, but at last all these enter Cañon of Desolation a few miles from its head. North of the Ta-vá-puts Plateau are the valleys of the White and Uinta Rivers. Nearly all the former and a large portion of the lower course of the latter are within the boundaries of Mr Graves' work.

Over the whole district assigned to Mr. Graves he extended the secondary triangulation. Owing to the peculiar topography of the country, his stations will average about twelve miles apart. He also made a connected plane-table map of the whole area, and complemented his work with orographic sketches.

In the southern portion of the area surveyed by Mr. Graves, considerable bodies of irrigable lands are found along the Grand, Green, San Rafael, and Price Rivers, and in the northern part, along the Green River and in the valleys of the Uinta and White Rivers, are other large tracts, on which the waters of the streams named can be conveyed at slight cost. Mr. Graves determined the extent, character, and location of these lands, and the amount of water carried by the streams throughout the area embraced in his work.

On the Ta-vá-puts Plateau are small forests of pine and fir, but generally Mr. Graves' district possesses no more timber than sufficient to meet the future local requirements of actual settlers.

Topographic work by Mr. Renshawe.—The district assigned Mr. Ren-

shawe was that embraced in the western portion of atlas sheet 75, an area of about 6,000 square miles. The eastern portion of this area is a broad table-land called the Wasatch Plateau, having an average elevation of about 9,500 feet, cut by deep valleys and drained from its very western edge toward the east by the Fremont, San Rafael, and Uinta Rivers. The western portion includes broad valleys, abrupt ranges of mountains, and one plateau of considerable extent. The principal valleys in this part are the San Pete, Juab, and Utah all having a general northern and southern trend, an average elevation of about 5,000 feet, and all are drained by the San Pete River and the streams flowing into Utah Lake. The mountain-ranges standing between the valleys are the Wasatch, rising in its highest peaks to 12,000 feet, the Lake Mountains, and the Tintic Hills, each reaching an altitude of nearly 7,500 feet.

The table-land called Gunnison Plateau has an area of about 750 square miles, and an average elevation of 8,000 feet. It is bounded on three sides by almost vertical walls, and is extremely rugged and difficult to traverse.

There is but little irrigable land in the eastern portion of Mr. Renshawe's district, but the broad valleys of the western portion contain large areas of excellent lands, and the numerous streams furnish a good supply of water. Mr. Renshawe determined the volume of water in every considerable stream, as well as the extent and localities of the irrigable lands, throughout his district.

On the plateaus and mountain-ranges are large quantities of excellent timber. On the head-waters of Price River and on Huntington Creek are extensive beds of coal, and on that portion of the Wasatch Range included in Mr. Renshawe's district are deposits of silver and galena.

Mr. Renshawe extended the secondary triangulation over the whole district assigned him, making stations at an average distance of about eight miles, and measuring all the angles of nearly every triangle in the extension. He also made a connected plane-table map of the whole area, and complemented his work with a complete set of orographic sketches.

Hypsometry.—The hypsometric work of this season rests on a primary base established at the general supply and rendezvous camp at Mount Pleasant, and connected by a long series of observations with the station of the United States Signal Service at Salt Lake City. At the base-station observations were made with mercurial barometers four times each day, and for eight days during the month hourly from 7 a. m. to 9 p. m. Mercurial barometers were carried by each field-party and observations made to connect every camp with the base-station. All the geodetic points and topographic stations were connected by observations with mercurial barometers either with the camps or directly with the base-station or both. All the topographic stations were also connected with each other by angulation, and from these stations the altitudes of all located points were determined by the same method.

Instruments—Base-measuring apparatus.—The apparatus used in measuring the base-lines from which the primary triangulation is developed consists essentially of wooden rods aligned and leveled on movable trestles or tripods, the contact being made by coincidence of lines instead of by direct abutment.

The rods are 15 feet long, one-half of an inch square, thoroughly dried, oiled, and varnished; they are supported in cases made truss-form to prevent sagging, and moved in these cases to make the contact by a rack and pinion motion. Both ends of the rod are shod with a plate of brass firmly fixed upon and half the width of the rod, or one-fourth of an inch, and so arranged that the plate upon the forward end of any rod projects by the plate upon the rear end of the preceding one in such a manner that both rods are in the same straight line. The line of coincidence is marked upon both plates and contact is determined by a magnifier.

A delicate spirit-level is attached to each case to adjust it horizontally and a thermometer inserted to determine the temperature of the rod. Two steel pins, by which the rods are aligned, are fixed on the cases directly over the center of the ends of the rods.

The tripods (or stands upon which the cases carrying the rods rest) have short double legs of the usual construction. Firmly fixed upon the tripod-heads are two uprights upon which a sliding cross-piece is clamped by thumb-screws. Above this cross-piece, parallel to and carried with it, is a second, which can be moved up or down three-fourths of an inch by means of a long slender wedge working between the cross-pieces, and furnishing an easy means of making the final adjustment of the rods in level. The uprights are several inches apart, and give sufficient range to align the rods, which is done by a theodolite placed in advance upon the line to be measured. Two or three rods and six or eight tripods are used. The rods are kept in a horizontal position, and, when the inequalities of the ground demand, vertical offsets are made with a theodolite. The line is first ranged out, and stakes set 500 feet apart along its length, then, with six men to work the apparatus, 3,000 feet per day can be measured with all the accuracy the refinements of the triangulation demand.

Theodolite.—The theodolite used in the triangulation is of a new pattern, embracing a number of improvements demanded by the character of the work. So far as possible the number of parts has been reduced by casting in a single piece parts that are usually combined by screws. In this manner the liability to derangement incident to the vicissitudes of mountain work is greatly reduced. The telescope has been enlarged as compared with the graduated circle, so as to make its defining power bear a greater proportion than usual to the refinement of graduation. The object-glass has an aperture of two inches and a focal length of twenty. The horizontal circle is ten inches in diameter, and reads by double verniers to five seconds of arc. The vertical circle is five inches

in diameter and reads to one minute. The instrument also embraces other improvements designed to secure greater stability, with ease and rapidity in manipulation.

Plane-Table.—In the topographic work the gradientor and sketch-book have been superseded by the plane-table and the orograph. The plane-table in use is of a pattern designed by Professor Thompson especially for work of this character. The drawing-board is made of a series of slats firmly fixed to canvas in such manner that it can be rolled into small compass for transportation; but when unrolled for work it is so secured by cross-pieces and screws that great stability is attained. When in use it is fastened to the platen of the orograph. The position of important features in the topography is fixed with an alidade by the usual methods of intersection and resection. Details are placed directly upon the map while they are still under the eye of the topographer, and much of the labor and uncertainty of description by notes is avoided, and the experience of five years in its use has demonstrated that the plane-table as modified is equally well-adapted to regions of mountains, hills, plains, or plateaus. The sketches produced are actual maps and not mere map material. They need only to be adjusted in conformity with the triangulation, and but slight adjustment is necessary. And it has been further demonstrated that a topographer in one field-season can extend his work over an area of about 7,000 square miles with all the accuracy necessary for the scale adopted by the Interior Department for the physical atlas of the Rocky Mountain Region, *i. e.*, a scale of four miles to the inch.

Orograph.—The orograph is an instrument new to topographic surveying, adapted to the requirements of this work by Professor Thompson. It consists essentially of a telescope erected above a platen or drawing-board, on which the movements of its optical axis are recorded. The telescope rotates about a vertical and about a horizontal axis, similarly to the telescope of a theodolite, and is connected by simple mechanism with a pencil which rests on a sheet of paper fixed to the platform. When the topographer moves the telescope so as to carry its optical axis over the profiles of the landscapes the pencil traces a sketch of the same. This sketch, being mechanically produced, is susceptible of measurement, and is a definite and authoritative record of the angular relations of the objects sketched. The instrument is also furnished with graduated circles, on which horizontal and vertical angles may be read to the nearest half minute, and these circles are used for the secondary triangulation. The orograph and plane-table are used conjointly, and their results furnish data for the production of contour maps. It is believed that by their introduction the quality of topographic work has been much improved without addition to its cost. When a topographer takes the field with these two instruments and plane-table sheets on which the primary triangulation has been previously plotted, he returns, with a map on which all of the geographic features to be delineated

have been determined by their angular relations, and the scenic characteristics necessary to give proper effect to the maps have been outlined by instrumental means. In this manner the subsequent construction of maps at the office, ready for the engraver, is reduced to a minimum of labor, while for the proper accuracy the topographer is not necessitated to resort to his memory for the appearance of the landscape, but only to the definite record.

Barometers.—The instruments used in the hypsometric work are Green's mercurial mountain barometers, Green's psychrometers, and aneroid barometers of the usual construction.

Cartography.—Much attention has been given to this subject for the purpose of determining the best method of representing the topography of the region surveyed, taking into consideration the character of the country, the more important facts to be embodied, and the scale adopted for the physical atlas of the Interior Department. The systems of cartography in use in this country and many of those of Europe have been examined and studied, and many experiments have been made in the office for the purpose of determining the best methods adapted to these circumstances and conditions.

For the physical atlas heretofore mentioned it is proposed to represent the topography by contour lines with auxiliary hatchings to indicate rock surface and shading for general reliefs, these so applied as not to obscure the contours. For special purposes hatched maps are used, for others contour maps, and for purposes relating to the discussion of geological structure maps are made by photographing or lithographing models or relief maps in plaster.

Classification of lands by Mr. Gilbert.—The survey under the direction of Professor Powell has been extended over the northern portion of Arizona and the greater part of Utah, but a broad strip along the northern end of the latter Territory was embraced in the survey made by Mr. Clarence King, under the War Department. It seemed desirable, however, to extend the classification of lands over this latter region, and this duty was assigned to Mr. G. K. Gilbert.

Mr. Gilbert took the field at Salt Lake City and traversed all of the Territory lying west, north, and northeast of that point, a tract comprising so much of the drainage basin of Great Salt Lake as lies in Utah. In this area is included the most valuable portion of the Territory, as well as the most sterile. A very small part of it will repay cultivation without irrigation, but this is exceptional, and in general the possibility of agriculture depends upon the possibility of artificial watering. The Bear River, the Weber, and the Jordan carry as much water as can profitably be used upon all the lands to which it is practicable to convey them by canals, and those lands were measured, in order to determine the agricultural capacities of the river valleys. The smaller streams, on the contrary, are inadequate to serve the arable lands through which they severally run, and the agricultural capacities of their valleys were as-

certained by measuring the volume of each stream. East of Great Salt Lake are great mountain ranges, the Wasatch and the Uinta, and large streams flow from their melting snows all through the summer season. The Bear, the Weber, and the Jordan flow to the lake, and the three rivers can be made to reclaim 800,000 acres of land in their valleys. This is 12½ per cent. of the district that they drain. West of the lake the plains are interrupted by mountains, but there are none of great magnitude; the snows of winter are dissipated too early in the spring to be of use for irrigation, and much of the land is an absolute desert. In a total area of 8,300,000 acres only 21,000 acres are of value for farming—one-fourth of one per cent.

These estimates are based upon the experience of the farmers of the district, who have practiced irrigation for thirty years, and have given it a greater development than can be found elsewhere in the United States. They have now under cultivation a third part of the irrigable lands of the Salt Lake Basin, and are utilizing many of the small streams to the full extent of their capacities. A careful study was made of their operations, for the purpose of learning the quantity of water necessary to redeem a given quantity of land under various conditions of soil and climate, and the resulting determinations were used in computing the areas susceptible of irrigation by the streams and parts of streams that are still unused. The greater part of the future extension of the cultivated areas will be accomplished only by extensive engineering works, including the damming of the principal rivers and the construction of long canals. Five million dollars is probably a moderate estimate of the cost of redeeming the 500,000 acres that are susceptible of reclamation, and the requisite capital will have to be concentrated upon a small number of large canals.

Since the first settlement of the Territory, in the year 1847, the water-supply has increased. It is reported by the citizens that each stream is now capable of irrigating a greater area of land than when it was first used. Creeks that once scantily watered a few acres of ground now afford an ample supply for double, treble, or even fifty times the original area. This increase has been accompanied by a rise of Great Salt Lake, which, having no escape for its water except by evaporation, has stored up the surplus from the streams. For the purpose of investigating the extent and the cause of the increase of the streams, Mr. Gilbert made a study of the fluctuations of the lake. It was a matter of common report that the surface of the water had been subject to considerable changes, and that on the whole it had greatly risen since its shores were first settled, but previous to the year 1875 no systematic record of its movements had been kept. In that year a series of observations was inaugurated by Dr. John R. Park, of Salt Lake City, at the suggestion and request of the Secretary of the Smithsonian Institution. A small pillar of granite, graduated to feet and inches, was erected at the water's edge near a rocky islet known as Black Rock.

The locality was then a popular pleasure resort, and the record was undertaken by Mr. J. T. Mitchell. Observations were made at frequent intervals for more than a year, but were then interrupted by reason of the disuse of the locality as a place of resort, and they have not since been resumed in a systematic way. To obviate a similar difficulty in the future, Mr. Gilbert caused a new record-post to be established near the town of Farmington, where the work of observation has been undertaken by Mr. Jacob Miller, and it is anticipated that in the future there will be no break in the continuity of the record.

In the interval from 1847 to 1875, during which no direct observations were made, there was nevertheless a considerable amount of indirect observation incidental to the pursuits of the citizens. The islands of the lake were used for pasturage, and the facilities for the transfer of cattle to and fro were greatly affected by the fluctuations of the water. A large share of the communication was by boat, and the frequent changes of landing-place which the boatmen were compelled to make impressed upon their memories the character and order of the principal oscillations. In pursuance of the inquiries instituted by the Secretary of the Smithsonian Institution, the testimony of the boatmen was compiled by Mr. Jacob Miller, and a history of the oscillations was deduced.

A similar and corroborative history has been derived by Mr. Gilbert from an independent investigation. Two of the islands used for pasturage are joined to the main-land by broad, flat bars, and during the lower stages of the lake these bars, being either dry or covered by a moderate depth of water, have afforded means of communication. It happens that the Antelope Island bar was in use until 1865, when it became so deeply covered that fording on horseback was impracticable; and that the Stansbury Island bar was first covered with water in 1866, and has been used as a ford with slight exception ever since. By the compilation of the testimony of those who have made use of these crossings, a continuous record was derived which cannot deviate very widely from the truth, and the work was checked by making careful soundings to ascertain the present depth of water on the Antelope Island bar.

From 1847 to 1850 there was little change beside the annual tide—a variation dependent upon the spring floods, and which makes the summer stage in each year from one to two feet higher than the winter. Then the water began to rise, and so continued until in 1855 and 1856 its mean stage was four feet higher than in 1850. This progressive rise was followed by a progressive fall of equal amount, and in 1860 the lake had returned to its first-observed level. In 1862 there began a second rise, which continued for eight years, and carried the water ten feet above the original level. Since 1869 there has been no great change, but the mean height has fluctuated through a range of about two feet.

As the lake has risen it has encroached upon the land, and the shores are in many places so flat that large areas have been submerged. At one point the water edge has advanced 15 miles, and the surveys of Capt.

Howard Stansbury and Mr. Clarence King show that from 1850 to 1869 the total area of the water surface increased from 1,750 to 2,166 square miles, or nearly 24 per cent. By this expansion the surface for evaporation was increased, so that the lake could return to the atmosphere the surplus thrown into it by the augmented streams.

Whatever land is at any time flooded by the lake becomes saturated with salt, and, if the water afterward retires, remains barren of vegetation for many years. The highest level reached by the water in storms is marked by a line of driftwood and other *débris*. Above this line there is usually a growth of grass and sage-brush, but below it nothing grows. Previous to the last great rise of the lake the storm-line was six feet lower than at present, and the intervening belt of land still retains the stumps and roots of bushes that have been killed by the advancing brine. The encroaching water overran the ancient storm-line in about the year 1866, and for the past eleven years it has covered ground which had been exempt from incursions of brine for a time sufficient to permit the rains to cleanse the soil, and for a further time sufficient to produce a growth of sage-brush. The whole period is as likely to have been measured by centuries as by decades.

Thus it appears that the last twelve years have witnessed an extension of the lake which is not only without precedent in the experience of the citizens of Utah, but is clearly an anomaly in the history of the lake. To explain it, and to explain at the same time the increase of the streams, there are two general theories worthy of consideration.

The first is that there has been a change of climate in Utah whereby the atmosphere is moister, so that the fall of rain and snow has become greater and the rate of evaporation has become slower. The second is that the industries of the white man, which have been steadily growing in importance for the last thirty years, have so modified the surface of the land that a larger share of the snow and rain finds its way into the water-courses, and a smaller share is returned to the air by evaporation from the ground. The latter theory, which is the one proposed by Professor Powell, is considered by Mr. Gilbert the more probable, and he finds reason to believe that the tax imposed upon the streams by the work of irrigation is more than repaid by the effects of the draining of marshes and the destruction of herbage and timber. A great volume of water is turned upon the cultivated fields, and from their moist surfaces is absorbed by the atmosphere without ever reaching the lake; but, on the other hand, the farmer has found it to his advantage to drain the beaver-ponds and other marshes, and thus check the evaporation from their surfaces, and the streams which he thereby rescues from dissipation are used in irrigation for a few months only, while for the remainder of the year they pay their tribute to the lake. The destruction of grasses by herds of domestic animals and the cutting of trees upon the mountains expose the ground to the sun and facilitate the melting of the snow; the removal of the grass opens the way also to a freer circulation of sur-

face-waters, so that the rain and melting snows are gathered more quickly and thoroughly into rills and streams; and both these influences increase the inflow of the lake.

This discussion has an important bearing upon the agriculture of the arid region, for if the theory favored by these gentlemen is the true one the work of irrigation can be pushed forward with the confident assurance that the supply of water is more likely to increase than diminish in the future; and it may even be possible, when the subject has been fully developed, to devise measures which shall directly promote the increase.

Geological work by Mr. Gilbert.—During the preceding summer Mr. Gilbert had discovered a peculiar series of phenomena produced by recent orographic displacements, and he has this year found opportunity to study them in numerous new localities. It appears that the system of faults and flexures, the system of upward and downward movements, by which the mountain-ranges and the valleys of Utah and Nevada were produced, have continued down to the present time. Evidence of recent movement has been discovered on the lines of many ancient faults. The ancient shore-line of Great Salt Lake, which is exhibited so conspicuously upon the surrounding mountain-slopes, and which must originally have been level, is no longer so, but has been shifted up and down by the displacement of the mountains. Its present altitude above Great Salt Lake was determined at four different points by spirit-level, and the determinations were found to range from 966 feet to 1,059 feet. The measurements by level were all made in the immediate vicinity of the lake, but the barometer indicates that at points more remote the discrepancy is several times greater.

These observations are valuable additions to our evidence that mountain-making is a work of the present as well as of past ages, and that the grand displacements by faults and folds are caused by slow and intermittent movements.

Mr. Gilbert also traced and mapped the northern portion of the ancient shore-line of the lake from Salt Lake City to Redding Spring, following its sinuous course for 900 miles in Utah, Idaho, and Nevada, and demonstrating that the ancient outlet he had discovered the preceding summer at Red Rock Pass was the only one by which the lake had ever discharged its water to the Snake River.

During the winter of 1876–'77, Mr. Gilbert prepared his report on the geology of the Henry Mountains, and the manuscript was sent to the printer. The Henry Mountains constitute a small group in southeastern Utah and stand quite by themselves. They are of a peculiar character and represent a type of structure that has never before been fully described. Mr. Gilbert's report is a monograph at once of the mountain group and of the type of mountain structure. The mountains are of igneous origin, but the rising lavas, instead of outpouring at the surface of the earth in the usual way, failed to penetrate the upper portions of

the crust and formed subterranean lakes or chambers. The strata lying above the lava lakes were upbent in the form of great bubbles, and from these bubbles of sandstone and shale, with their cores of trap, the erosive agents of the air have carved the mountains. The mountain structure is thus two-fold, comprising first volcanic upheaval, and second atmospheric degradation. To aid in the discussion of the first element of structure, Mr. Gilbert constructed a stereogram of the district, in plaster, exhibiting the forms due to upheaval as they would appear if unmodified by degradation. He prepared also a topographical model, exhibiting the same forms as actually modified; and the two models will be reproduced by photography to illustrate the report. The treatment of the second element of structure is of a thorough character and includes a discussion of the general principles which control the sculpture of the land surfaces of the earth by rains and rivers. The volume is ready for the binder.

Geological work by Captain Dutton.—Captain C. E. Dutton resumed his exploration of the same field which he has been studying for three years, having recognized in it a certain unity which renders it eminently adapted to an important monograph. The region explored by him is centrally situated in the Territory of Utah, extending from Mount Nebo in the Wasatch, nearly southward a distance of about 180 miles, and having a maximum breadth of about 60 miles. It possesses certain features which serve to distinguish it both topographically and geologically, and he proposes to call it the District of the High Plateaus of Utah. It consists of a group of uplifts now standing at altitudes between 9,000 and 11,500 feet above sea-level, while the general platform of the country is from 5,000 to 7,000 feet high. The plateaus have been carved out of this platform by great faults, and the general structure corresponds closely to that described by Professor Powell under the name of the Kaibab structure, and illustrated by him in his section of the region traversed by the Grand Cañon of the Colorado. The relations of this belt of high plateaus to the regions adjoining are of special interest. At the close of the cretaceous the country lying to the eastward of it passed by gradation from an oceanic to a lacustrine condition, the intermediate stage presenting, doubtless, a strict analogy to the condition of the Baltic. This eocene lake area now constitutes the southern part of the drainage-system of the Colorado River. During cretaceous and eocene time, the area now occupied by the Great Basin was dry land, and its denudation must have furnished a large part of the sediments which were spread over the bottom of the great lake. The movements which took place during the eocene at last resulted in the desiccation of the lake, and though a strict chronological correlation to European and other divisions of time cannot be made with certainty, it may be provisionally inferred that this desiccation was completed before the commencement of the miocene. It was brought about by the more rapid uplifting of the lake area than that of the Great Basin, until at last the former

area became the loftier of the two, thus reversing their relative altitudes. The lake area is now a portion of the so-called plateau country, and since the commencement of the miocene (para-miocene) has been subject to a great and continuous erosion. The District of the High Plateaus occupies a portion of a narrow belt separating the plateau country from the basin province, and therefore stands upon the locus of the ancient shore-line, which, in the lacustrine stage, bounded the two areas. To that shore-line they stand in an intimate and remarkable relation. To its trend the great displacements maintain, not merely a general parallelism, but an approximation to strict parallelism both in totality and in detail, which would not have been anticipated, and which cannot be purely accidental, and seems to point to some definite determinative association between the littoral deposits and the great lines of displacement. The great structural features are these faults and their equivalent monoclinal flexures. They are remarkably persistent, extending in parallel courses throughout the entire length of the region surveyed. One of them, the great Sevier fault, becoming here and there a monoclinal flexure, has been traced continuously over a length of 240 miles, and others of nearly equal persistence have been noted. The High Plateaus belong to the Plateau country, for notwithstanding the great amount of dynamical energy indicated in their uplifting, they preserve in a remarkable manner the plateau type of structure, which is distinguished sharply from the arched, flexed, and tilted types prevailing in other disturbed localities. There is an abrupt transition from this plateau structure to that found in the adjoining basin. There are some localities where one may hurl a stone from one province to the other, and in general it may be said that the dividing line must pass within a single range or table. The plateau province seems to stand here in strict correlation to the tertiary beds; where the tertiaries end there also end the plateaus. The relation between the tertiary and cretaceous throughout this belt is one of general unconformity; in many places where the contacts are seen, the tertiary is revealed lying across the upturned and eroded edges of the cretaceous, showing clearly a break between those portions of the two series which are here preserved.

But of all the features displayed by the high plateaus the most remarkable are the manifestations of former volcanic activity. Both in area and thickness the volcanic emanations are very extensive. They cover more than 5,000 square miles, and sections of 4,000 to 5,000 feet are presented without revealing the lowest beds. The greater part of the eruptions took place after the lake basin had been drained or had shrunken to limits outside of the district, for sedimentary beds have not been found intercalated between the various flows, but always underlie them. It is therefore impossible to fix with great precision the commencement of the outbreaks; but the general indications are that they began very soon after the close of the lacustrine period, and they may have commenced still earlier. The eruptive epoch was undoubtedly a

long one. The individual flows are very numerous, and represent all the great groups of eruptive rocks. In many cases the quantity of material extravasated is so great that the eruptions may well be called massive; not, however, of such marvelous extent as are asserted to have been poured forth from fissures during the basaltic period in Oregon and Northern California ; but there are many individual sheets which surpass in magnitude any which is known to have emanated during recent or modern times from any existing volcanic vent at a single eruption. From what openings these masses were extravasated it is usually difficult to fix with certainty and precision. So vast are the accumulations and so expansive are the sheets, and, at the same time, so numerous, that wheresoever they were emitted the earlier vents must have been buried by later deluges of lava ; and even the more recent vents, except in the case of the latest basalts, have been swept away by slow erosion in the long period which has elapsed since their activity was extinguished. There are, however, still remaining, distinct traces of localization of eruptive activity in the form of greater accumulations, at some points from which, in most directions, the total thickness of the volcanic series appears to attenuate. Moreover, in those central localities of maximum accumulation there appears to be a large amount of what might be called, in a certain sense, unconformity of the various eruptions, and greater irregularities in their bedding, as compared with the more even layers and more regular distribution of the sheets more remote from these centers. This fact appears to be of general application also to existing volcanic regions of great extent. Captain Dutton has succeeded in locating at least five areas, from which the various overflows appear to have emanated, and believes that further research might result in the determination of others.

At the time these eruptions were in progress it is probable that the country was not an elevated one as at present, though it may have been a rising area. The great displacements, consisting of faults of extraordinary length and persistency, took place after the close or during the decadence of the principal eruptions, and it was at this latter epoch that the greater part of the general elevation of this portion of the plateau province occurred. During its progress many eruptions must have taken place, and their later age is readily identifiable ; but none of them were comparable in extent and in the volume of ejected materials with older eruptions prior to the great displacements. Although it is ordinarily not difficult to determine whether a particular event preceded or followed some other within the locality, there seems to be no way of correlating these different events strictly with the epochs which are designated by the sedimentary formations of the adjoining country, and it is therefore impossible to determine the exact period in the chronological scale at which the faulting took place, further than the fact that it must have occurred long enough after the close of the eocene to allow for the accumulation of these vast bodies of volcanic

beds. This may carry the period of faulting far into the miocene period, or possibly as far as the commencement of the pliocene. But while the first stage in the activity of these ancient volcanoes was undoubtedly the greatest, and accompanied by an incomparably greater amount of extravasation, it by no means constitutes the whole of it. Even after the great displacements, and after the principal topographic features of the country, depending upon structure as they now exist, had received their shape, minor eruptions continued; they present, however, a somewhat remarkable fact. The later eruptions did not take place from the same centers as the earlier ones, but show a tendency to recede from them and to occur around the borders of the older volcanic district. The central portions of the volcanic area are unquestionably the oldest, while the younger ones are found around their borders, and sometimes at considerable distances.

One point which during the study of this region has engaged the careful attention of Captain Dutton has been to ascertain whether it presents any such sequence in the lithological character of the eruptions as is asserted by Baron Richthofen to prevail in the volcanic districts of Europe, South America, Asia Minor, and the Sierra Nevada. This asserted sequence has engaged the profound attention of most vulcanologists and is of great importance in relation to all questions bearing upon the origin and causes of volcanic action. Although at first disposed to doubt the prevalence of this sequence, and not favorably impressed with the speculations and theoretical views of Baron Richthofen, Captain Dutton has reached the conclusion that the high plateaus of Utah exhibit in a decided manner essentially the same sequence which Richthofen claims for other volcanic regions. The earliest eruptions consist of rocks agreeing well in lithological characteristics with those described by Richthofen under the name of propylite. This rock is usually concealed if it exists in any great quantities by the later flows, but is in several places brought to light partly by the great displacements, and partly through the agency of erosion, and wherever found it is seen to occupy the lowest position of all. It is also worthy of note that this rock is found at those points which constitute the centers of eruption before referred to, showing that the activity which it ushered in continued to have its seat through a long cycle in and about the same locality. The propylite is succeeded by a rock answering to Richthofen's description of hornblende andesite, which is usually overlaid by a rock rich in augite with triclinic feldspar which may be termed augitic andesite. Still higher in the series are found immense masses of trachyte which, however, is frequently intercalated with dolerite. The variety of the trachytes is very great; so great, indeed, that were it not for the persistence of certain mineralogical as well as textural characteristics which are universally accepted as being distinctive of that group of rocks, one might feel strongly tempted to make numerous subdivisions of them into a series of groups. The extremes of the varieties of the trachytes

might be represented at one end by a coarsely granular micaceous rock composed chiefly of orthoclase, and is sometimes hornblendic and sometimes augitic, at the other end a highly porphyritic trachyte consisting of well-developed orthoclase feldspar imbedded in a fine paste highly charged with peroxide of iron. Between these masses of trachyte are intercalated, though in subordinate quantities, beds of dolerite showing distinct crystals of striated feldspar with great abundance of augite and magnetite. In the earlier and grander periods of the eruptions the following sequences may therefore be recognized: first, propylite; second, andesite; and, third, interblended trachyte and dolerite. Still later than these, and occurring at new centers of eruption, were outpours of rhyolite, while last of all were erupted around the outskirts of the district great quantities of true basalt. There does not appear to be any single locality where all the groups of rocks are found superposed; nevertheless the relative ages do not admit of any doubt, whether the various beds are superposed or not; but while furnishing a general verification of the sequence, the district of the High Plateaus presents the fact with certain modifications which may be set forth in the following manner: In the lithological scale propylite and hornblendic andesite are very nearly intermediate between the extremes of acid rocks represented by rhyolite, and basic rocks represented by basalt. Taking propylite as a starting-point in the scale of classification, we find two divergent series proceeding on the one hand toward the acid end of the scale, and on the other toward the basic end. As we follow the eruptions down into the later epochs, we find that both series are represented in a certain sense independently of each other so that they intercalate; the acid becoming at one end more acid with the progress of the volcanic cycle, and the basic rocks becoming more basic. Each series seems to pursue its own order and to be subject to its own law, so that, being originally divergent, they become more and more widely separated in their lithological characters as the cycle proceeds. Thus at the commencement of the activity we have propylite and hornblendic andesite, which are closely assimilated to each other in their physical characteristics; at the middle stage we have trachytes and moderately basic dolerites, which are moderately separated, and at the close we have rhyolites and basalts, which stand at the opposite ends of the scale.

Plan of publication.—In the geological branch of the work the plan has been adopted as far as possible of publishing monographs, each embracing all the studies made by the corps of any particular region to which it relates, preferring this to a system of annual reports consisting of *résumés* of the field-notes of each season. In the preparation of these monographs, relief maps or plates are constructed on a scale of two miles to the inch or larger, vertical and horizontal scales being equal; and to correspond with each relief map a stereogram in plaster is constructed on the same scale, designed to exhibit such a surface as would appear had there been no degradation by atmospheric agencies, but displace-

ment only. By this means the characteristics of displacement can be studied independent of the phenomena of degradation, with which, in nature, they are always associated, and by which they are more or less obscured; and a comparison of the stereogram with the relief map gives approximate quantitative results of degradation; that is, the two factors of mountain structure, elevation by displacement and degradation by rains and rivers, are separated, that each may be considered independent of the complicating conditions of the other.

Geological illustration.—Much attention has been paid to the graphic representation of the important features of geological structure. The Rocky Mountain Region has proved to be one of great interest in this branch of investigation, because of the peculiar features of its physical geography. Long and towering escarpments are found, deep cañons with precipitous walls are numerous, its hills and mountains are often without soil and vegetation, accumulations of subaerial or glacial drift are infrequent, and thus the general rock-structure is well revealed. Several new methods of illustration have been devised, some of which have already appeared in the publications of the survey.

Ethnographic work.—During the season the ethnographic work was more thoroughly organized, and the aid of a large number of volunteer assistants living throughout the country was secured.

Mr. W. H. Dall, of the United States Coast Survey, prepared a paper on the tribes of Alaska, and edited other papers on certain tribes of Oregon and Washington Territory. He also superintended the construction of an ethnographic map to accompany his paper, including on it the latest geographic determinations from all available sources. His long residence and extended scientific labors in that region peculiarly fitted him for the task, and he has made a valuable contribution, both to ethnology and geography. With the same volume was published a paper on the habits and customs of certain tribes of the State of Oregon and Washington Territory, prepared by the late Mr. George Gibbs, while he was engaged in scientific work in that region for the government. The volume also contains a Niskwalli vocabulary, with extended grammatic notes, the last great work of the lamented author. In addition to the map above mentioned and prepared by Mr. Dall, a second was made, embracing the western portion of Washington Territory and the northern pa t of Oregon. The map includes the latest geographic information, and is colored to show the distribution of Indian tribes, chiefly from notes and maps left by Mr. Gibbs. Much of the linguistic material of this volume was collected by correspondents of the Smithsonian Institution, and turned over to Professor Powell to be consolidated with materials collected by members of his corps.

These papers form a quarto volume of 361 pages, entitled Contributions to North American Ethnology, Volume I, the first of a series to be published on this subject.

Volume II, relating to the tribes of the eastern portion of Washington

Territory and the State of Oregon, was partially prepared for the printer, but it was thought best to withhold its publication until further materials were collected from that region.

The third volume of the series has been published. This relates to the Indians of California. Mr. Stephen Powers, of Ohio, has been engaged for several years in the preparation of this volume. The first part contains an account of the habits, customs, mythology, &c., of the several tribes. At our earliest knowledge of the Indians of California they were divided into small chieftaincies speaking diverse languages and belonging to radically different stocks, and the whole subject was one of great complexity and interest. The materials collected by Mr. Powers were sufficient to successfully unravel the difficult problem relating to the classification and affinities of a very large number of tribes, and his account of their habits and customs is of much interest. A number of vocabularies of the Smithsonian collection are published with those of Mr. Powers. The linguistic portion of the volume was edited by Professor Powell.

The volume is accompanied by a map of the State of California, compiled from the latest official sources and colored to show the distribution of linguistic stocks.

The Rev. J. Owen Dorsey, of Maryland, has been engaged for more than a year in the preparation of a grammar and dictionary of the Ponka language. His residence among these Indians as a missionary has furnished him favorable opportunity for the necessary studies, and he has pushed forward the work with zeal and ability.

Prof. Otis T. Mason, of Columbian College, has for the past year rendered the office much assistance in the study of the history and statistics of Indian tribes.

Brevet Lieut. Col. Garrick Mallery, U. S. A., has during the year been engaged in the study of the history and statistics of the Indians of the United States. His researches lead him to the conclusion that the generally received opinion that a very large Indian population occupied this country at the time of its discovery is erroneous; that the supposed rapid and general decadence of the Indians arising from contact with civilization is not sustained, and that, when circumstances have not rendered it impossible, they are making reasonable progress toward civilization, together with which in many instances their numbers have increased. No final publication on the subject has yet been ssued, but he has read papers before the Philosophical Society of Washington, and other scientific bodies, to invite the attention of ethnologists to the subject. He has also been engaged in preparing the history and bibliography of the Klamath, T'sinuk, Wayïletpu, Sahaptin, and other families of Oregon, and his papers on this subject will appear in the second volume of Contributions to North American Eth nology.

In March last Mr. Albert S. Gatschet was employed to assist in the

study of Indian languages, and during the spring months his time was occupied as an assistant in compiling the bibliography of the North American languages. During the summer and autumn months he visited a number of tribes in Oregon for the purpose of collecting vocabularies and grammatic notes. On his way to the field he stopped at Ogden, where he found a tribe of Shoshoni Indians from whom he procured a vocabulary of about five hundred words.

In Chico, Butte County, California, he stopped one week to visit the Michópdo Indians, a branch of the Maidu stock, where he collected linguistic material of value. From Chico he proceeded directly to the Klamath agency, in Southern Oregon, where eight weeks were devoted to the study of the language of the Klamath Indians, a branch of the Modok family. Mr. Gatschet had previously studied this language by obtaining words from Modok Indians visiting Washington and New York, and his work at the Klamath agency was a continuation of such study. Altogether he has collected a vocabulary of about five thousand words, also many sentences and texts, on historic and mythologic subjects, arranged with interlinear translations.

The numerical system of this language is quinary, and the numerals above eleven have incorporated particles giving them a gender or classifying significance, apparently based upon form. The subject and object pronouns are not incorporated in the verb; the personal pronouns differ from the possessive; and a true relative pronoun exists. An important characteristic of the language is the use of prefix particles in nouns and verbs indicating form, and the reduplication of the first syllable, which is usually the radical syllable, for the purpose of showing distribution. It is often equivalent to our plural. It occurs in the singular of adjectives indicating shape and color; in augmentative and diminutive nouns and verbs; in iterative and frequentative verbs; and forms the distributive plural of many substantives, adjectives, numerals, verbs, and adverbs.

From the Klamath agency Mr. Gatschet proceeded to the Grande Ronde agency in the northwestern part of Oregon. On his way he stopped at Dayton and made collections of Shasta and Umpqua words from reliable Indians. On the Grande Ronde agency are found a large number of tribes and remnants of tribes, which were collected there after the Oregon war of 1855–'56; and with the exceptions of the Klikatats they are all from Western Oregon. The following is a classification of the linguistic stocks now on this reservation: Tinneh, Siletz, Wayiletpu, Shasta, T'sinuk, Sahaptin, Selish, Modok, and Kalapuya. The Kalapuya once occupied almost the whole extent of the beatiful and fertile Willamette Valley, and one branch of this stock, the Yonkálla, even extended into the Umpqua Valley.

The Tuálati language, a dialect of the Kalapuya stock, was the one studied by Mr. Gatschet, and from his notes the following characteristics appear: The phonetics are strikingly soft and harmonious, and

though consonants are often assembled in large clusters they never offend the ear, nor do they seem unpronounceable to Americans. A large number of words begin with vowels, especially with *a*, *i*, and *u*. The substantive, adjective, and numerals are not inflected for case, as in the Modok. Adjectives and numerals and some substantives are varied to indicate the plural number. The parts of speech are very imperfectly differentiated. The personal and possessive pronouns have the same form. Gender as a distinction of sex is indicated in the singular of subject pronouns, but not in the plural. Prefix particles are extensively used to express the mood, voice, and tense of the verb, and the same particles fulfill this function in the noun. The personal pronouns of the direct object differ greatly from the pronouns of the indirect object; and every one of the three persons, in the singular and plural, possesses a different series of direct and indirect objective pronouns. The conjugation of the transitive verb differs in many particulars from that of the intransitive. There appears to be structural affinities between the Kalapuya and Selish stocks. Over three thousand words, many hundred sentences, and valuable ethnologic texts were collected.

Besides the Michópdo, Modok, and Tuálati, before mentioned, Mr. Gatschet also collected vocabularies and sentences of the following languages: Shoshoni, Achomâwi, Shasta, Wintun, Waccanéssisi, Wasko, Klákamas, Mólele, Nestucca, Yamhill, Lukamáyuk, and Akantchuyuk. In the collection of all these vocabularies the "Introduction to the Study of Indian Languages," prepared for the Smithsonian Institution by Prof. J. W. Powell, was used.

Dr. H. C. Yarrow, U. S. A., now on duty at the Army Medical Museum, in Washington, has been engaged during the past year in the collection of material for a monograph on the customs and rites practiced in the disposal of the dead among the North American Indians. To aid him in this work circulars of inquiry have been widely circulated among ethnologists and other scholars throughout North America, and much material has been obtained which will greatly supplement his own extended observations and researches.

During the summer some interesting work was done in the examination of the stone graves of Tennessee, and valuable collections were made. Professor Powell has co-operated with the Institution in providing for a more thorough examination of the archæology of the islands off the shore of Southern California. This exploration was made by Rev. Stephen Bowers, of Indianapolis, Ind., and his report will be published with the papers of the Survey.

A small volume, entitled "Introduction to the Study of Indian Languages," has been prepared. This book is intended for distribution among collectors. In its preparation Professor Powell was assisted by Prof. W. D. Whitney, the distinguished philologist of Yale College, in that part relating to the representation of the sounds of Indian languages. A few preliminary copies have been printed and distributed

among gentlemen interested in the study of Indian languages, for such additions and emendations as may be suggested preparatory to final publication. A tentative classification of the linguistic families of the Indians of the United States has been prepared. This will be published as soon as the bibliography is ready.

In pursuing these ethnographic investigations it has been the endeavor, as far as possible, to produce results that would be of practical value in the administration of Indian affairs; and, for this purpose, especial attention has been paid to statistics, the progress made by the Indians toward civilization, and the causes and remedies for the inevitable conflict that arises from the spread of civilization over a region inhabited by savages. It is believed that the labors in this direction will not be void of useful results.

Survey of the Black Hills.—In 1875 a reconnaissance survey was made of the Black Hills of Dakota, by Mr. Walter P. Jenny, with a corps of assistants, under the direction of the honorable Secretary of the Interior. On the return of the party from the field, Mr. Jenny's report, relating to the mineral resources of the country, was immediately published; but the geographical and geological report was unfinished at that time. This latter work was left in the hands of Mr. Henry A. Newton, his geological assistant, to be completed. On May 28, 1877, at the request of Mr. Newton, the completion of the work was placed under the direction of this survey, by order of the Secretary of the Interior.

On consultation with Mr. Newton it appeared wise that he should visit the field again, for the purpose of determining certain doubtful points in the geological structure, and to insert on the maps the position of the several towns and roads established in that region since the discovery of gold; and Mr. Newton was employed for this purpose. He had been in the field but a short time when he was prostrated by the sickness which resulted in his death. Previous to his departure he completed his report on the geology of that country, and the map had been placed in the hands of an engraver; the whole embodying all the facts discovered up to that time. Thus, happily, his work will not be lost. It is expected that his report will be published, during the present winter, in the shape in which it was left by him.

The death of Mr. Newton makes a serious break in the ranks of the younger and more active geologists of America. He possessed rare abilities, had much experience in field operations, and had received thorough and wise training; and his work in other fields had exhibited his ability. But the great work of his short life will doubtless be his report on the geology of the Black Hills of Dakota.

During the past six years one branch of the work of the Survey has been considered of paramount importance, namely, the classification of lands and the subjects connected therewith. The object has been to determine the extent of irrigable lands, timber lands, pasturage lands, coal lands, and mineral lands. In general the lands that are cultivable

only through irrigation are limited by the supply of water. There are some exceptions to this. Where streams are found in narrow valleys or run in deep cañons, the limit of agricultural land is determined by the extent of the areas to which the water can be conducted with proper engineering skill. In the study of this subject many interesting and important problems have arisen, and many valuable facts have been collected.

From the survey of the timber lands one very important fact appears, that the area where standing timber is actually found is very much smaller than the areas where the conditions of physical geography are such that timber should be found as a spontaneous growth; that is, the *area of timber* is but a small fraction of the *timber region.* The destruction of the timber in such regions now found naked is due to the great fires that so frequently devastate these lands; and the amount of timber taken for economic purposes bears but an exceedingly small ratio to the amount so destroyed. Hence the important problem to be solved is the best method by which these fires can be prevented.

Another subject which has received much attention is the utilization of the pasturage lands; and still another, the best methods of surveying the mineral lands for the purpose of description and identification, that the owners of mines may be relieved of the great burden of litigation to which they are subjected by reason of the inaccurate and expensive methods now in vogue.

UNITED STATES GEOGRAPHICAL SURVEYS WEST OF THE ONE-HUNDREDTH MERIDIAN, IN CHARGE OF FIRST-LIEUT. GEORGE M. WHEELER, CORPS OF ENGINEERS, U. S. ARMY, IN 1877.

The geographical surveys west of the one hundredth meridian, under First-Lieut. George M. Wheeler, Corps of Engineers, United States Army, for the field season of 1877, were conducted in three sections, named the Colorado, Utah, and California sections, respectively. In each section were two main parties, besides special parties in the Utah and California sections, making ten in all. One of the special parties in Utah, being under the immediate command of Lieutenant Wheeler, operated in the northern part of that territory and southern part of Idaho; others under his immediate direction were engaged in Utah, Idaho, and Nevada.

(1) The parties of the Colorado section, under Lieutenants Bergland and Morrison, operated from Fort Lyon, Colo., the former wholly in Colorado, and the latter mostly in New Mexico, and to some extent in Colorado and Texas. The special field of the former was in the Uncompahgre region, the topography and drainage of which were determined, and the Gunnison and Tumichi rivers gauged, and mines of the locality examined. The country examined is well watered, with plenty of fish and game, rich minerals in the mountains, and portions of the valley of the Uncompahgre good for agricultural purposes. For the greater part of the season the party under Lieutenant Morrison was

engaged in Central New Mexico, south and southeast of Santa Fé, in the area of atlas-sheets 77 D and 84 A and 84 B. Throughout the Rio Grande and Fort Stanton sections, good agricultural lands were found, and copper, silver, and gold deposits in the mountains. Ancient pueblos, among them the "Gran Quivira," were visited, and a cave, in the limestone near Fort Stanton, was explored for the distance approximately of one mile.

The various parties in the Utah section took the field from Ogden, that one under Lieutenant Tillman operating in the area between the meridians of 111° and 112° 20′ west longitude, and the parallels of 43° 10′ and 41° 40′. The work was connected with a base measured at Ogden. The whole area was triangulated and numerous secondary points located. About 8,000 square miles were surveyed, and the data collected to complete atlas-sheets 32 D and 41 B. In September, Lieutenant Young, Corps of Engineers, took charge of this party, and Lieutenant Tillman proceeded to Fort Ellis, Montana, where he measured a base-line in the vicinity of the main astronomical station at Bozeman, for future use. Lieutenant Birnie, in charge of Utah party No. 2, operated in an area connecting with the geological exploration of the fortieth parallel under Clarence King, with a view to finishing the work on atlas-sheets 41 A and 32 C, containing approximately 6,800 square miles. This area includes the great basin north of Great Salt Lake; the drainage basin of Snake River; several detached mountain groups, which were examined for low passes, these passes being also examined as to their altitude compared with the highest beach-marks of the ancient Lake Bonneville; and north of Snake River an unbroken lava desert, remarkable for its rock surface, almost entire absence of water, and fine grazing near the few water-courses. In the mountains some timber was found, and they have been prospected for silver in the Clear Creek and Black Pine regions, from which a few streams run toward Great Salt Lake, to be lost, however, in the neighboring valleys. Cattle-raising is extensively carried on upon the grazing-fields in the vicinity of the numerous tributaries of Snake River, running south from the mountains. Snake River was gauged and examined for fords, and the party made several trips outside the area particularly alluded to, one being for the purpose of determining the course of Wood River, and to examine and locate the Great Shoshone Falls.

The parties of the California sections took the field from Carson, Nev., in June. One under Lieutenant Symons, Corps of Engineers, occupied the area of atlas-sheets 38 B, 38 D, and 47 B, for the prosecution to completion of the work therein. A side party made the detour of Pyramid Lake for the purpose of occupying outlying triangulation stations, the main triangulation being extended over the whole area to be surveyed. The main party worked from Honey Lake Valley north to Eagle Lake, Horse Lake, Smoke Creek, the Madelin Plains, and by the Warner Range to the west of Goose Lake to Drew's Valley, in Ore-

gon, all of which area was occupied with a view to correct topographical data, and the triangulation carried as far north as Beatty's Butte.

Returning by the east shore of Goose Lake, Granite Mountain, and Honey Lake, to Verdi, Nev., a base line was measured and the triangulation of 1876 and 1877 connected. The country surveyed by this party embraced parts of California, Oregon, and Nevada, and is of volcanic origin. Water is scarce, and except in the valleys there is scanty vegetation.

The party under Lieutenant Macomb pursued its labors principally in the area of atlas-sheets 47 D and 56 B; its route was up Carson Valley and cañon into Hope Valley to Placerville, Cal.; thence north and among the headwaters of the American and Yuba rivers, connecting with work of the previous year. In August it again moved from Placerville eastward across the Sierras, occupying numerous triangulation points, to Silver City. Thence it moved south to Sonora Pass, and as far as Bridgeport, Cal. From thence its course was north by the Sweetwater Mountains, and west by San Andreas, to Silver City, for supplies, at which point the geologist was occupied for nearly a month in the mountains east of Carson Valley, and the field-season closed. The following summary shows a number of the principal instrumental observations made:

Number of azimuths measured, 13; number of sextant latitude stations occupied, 118; number of main triangulation stations occupied, 108; number of secondary triangulation points occupied, 262; number of three-point stations occupied, 1,414; number of meander stations occupied, 11,227; number of variations of the needle taken, 423; number of miles measured, 9,728; number of cistern-barometer stations occupied, 1,255; number of aneroid stations occupied, 7,558. The highest altitude noted was 14,415 feet, and the lowest 900 feet, the latter at San Andreas, Cal.

The special parties operating in Utah, Idaho, and Nevada, other than Lieutenant Wheeler's, consisted of Dr. Kampf, Miles Rock, and Francis Klett, and their assistants. The results of their labors consist in the establishment of a number of main triangulation stations, the measurement of three bases, the occupation of a number of trigonometric stations in the valley of the Great Salt Lake about Ogden, and the measurement of several minor traveled routes from the Union Pacific Railroad to the northward. The special parties in the California section were occupied, one, under Mr. Weyss, in the Lake Tahoe region, productive of very interesting topographical results; and one, consisting of John A. Church, mining engineer, and A. Karl, in a critical survey of the Comstock Mines, an interesting preliminary report of which has been made by Mr. Church. The examination of the Washoe mining region, in which the famous Comstock lode is situated, consists of an elaborate contour survey of the entire area covered by the mining and milling works, delineated upon a scale of one inch to five hundred feet, each

contour representing a vertical distance of fifty feet. The field-work for this purpose is now completed. Cross-sections at horizontal distances of one hundred feet are being made; the workings along each of the opened levels of the numerous mines are being mapped, and a longitudinal section on an appropriate scale will show most accurately the relative position of the mines, their present openings, and the lines of all tunnels, including the Sutro Tunnel. In this work the engineers and surveyors of the region have gratuitously contributed the use of their maps and tracings made by them for the several mining companies, and especially Mr. I. E. James, whose name in this relation has been connected with the Comstock Mines almost continuously since their early working. The examinations proposed to be made include the subject of temperatures, ventilation, drainage, and treatment of ores. In this work, that must cover a number of years in order to prove successful, the officer in charge will be able to devote some of his time, and the different problems involved will be submitted to experts in the branches of geology, mineralogy, and metallurgy.

Mr. Henshaw, zoölogical assistant, accompanied party No. 1 of the California section as far as Southern Oregon, and largely supplemented the collections made during the previous year illustrative of the zoölogy of that interesting region. The habits of the water-birds were carefully studied, and large collections made of skins and eggs. A thorough collection of fishes was also made, and the discovery of a large and fine trout, one of two species inhabiting Lake Tahoe, is announced. The *Lepidoptera*, *Orthoptera*, &c., gathered have yet to be examined and reported upon.

Mr. A. R. Conkling accompanied party No. 2 as geological assistant, and examined the eastern and western slopes of the Sierras, in continuation of previous examinations. Some important mining stations were visited, including Bodie, where new and promising discoveries of gold-bearing quartz have been recently found, and Aurora, which is again becoming prominent. The country examined, however, offers few problems of interest to the geologist, presenting a monotonous uniformity of structure, granitic rocks largely predominating, with occasional evidences of volcanic outbursts. Volcanic breccia abounds in some sections. Evidences of glacial action, so abundant at Lake Tahoe, were found at various points southward, notably about the headwaters of the Stanislaus, American, and Mokelumne rivers. A small collection of vertebrate fossils of the Tertiary age was made near Carson, Nev.

At the Washington office the usual number of draughtsman have been continuously engaged upon the topographic sheets in course of construction, upon scales of one inch to eight miles, one inch to four miles, one inch to two miles, one inch to one mile, and one inch to two thousand feet. The number of sheets so projected as to conjoin, covering the entire area of survey, is 95, each 19x24 inches. Many of these sheets are now complete, and thirty-two sections to be represented by

distinct sheets have been entered. The geological maps are based upon the topographical-atlas sheets, and have corresponding numbers. The following sheets appear with the annual report submitted to the Chief of Engineers, June 30, 1877, viz: Atlas-sheet 53 C, embracing portions of Central Colorado, and showing the drainage-basin of the South Platte River; 61 B, Central Colorado, showing portions of the drainage basin of the Rio Grande, Arkansas, Gunnison, and South Platte rivers, indicating economic features; 61 C, sub, part of Southwest Colorado, and drainage-basins of the Gunnison, Rio Grande, Animas, Miguel, and Uncompahgre; 61 D, embracing portions of Southern Colorado, and lying principally in the drainage-basin of the Rio Grande; 65 D, embracing a portion of Southeastern California, showing the interior basin of Panamint and Death Valleys, Amargosa River and Owens Lake drainage; 69 B, Southern Colorado and Northern New Mexico, lying principally in the drainage-basins of the Rio Grande, Conejos, Chama, and Navajo rivers; 70 A, Southern Colorado and Northern New Mexico, showing the drainage-basins of the Purgatory and Canadian rivers, and Costilla and Culebra creeks; 70 C, Northern New Mexico, and drainage-basins of the Canadian and Mora rivers; and 77 B, embracing portions of Central New Mexico, and lying in the drainage-basins of the Rio Grande and Pecos rivers.

All these sheets except 53 C and 61 D show economic features of the areas represented by arrangement of colors.

A temporary field office has been established at Ogden, where time and meteorological observations are being taken, and the further topographical and hydrographical survey of the Great Salt Lake basin is being carried forward by a special party.

During the year, volume IV of the quarto reports on Paleontology has been published, and volume II, on Astronomy and Barometric Hypsometry, is passing through the press; as is also a catalogue of the mean declinations of 2,018 stars, which useful work will supply all the needed latitude stars for the entire area west of the one hundredth meridian from latitude 30° to 60° N. During that part of each year, *i. e.*, from May to December, in which the season is best adapted for such observations, it will appear that this Survey, having at its base the systematic collection by the most scientific method of topographical data for an accurate map of the Western mountain region, has gone on with its usual vigor, having now prosecuted its labors in the States and Territories of Texas, Colorado, Nebraska, California, Nevada, Oregon, New Mexico, Arizona, Utah, Wyoming, Idaho, and Montana, and already published original maps covering an area of 242,598 square miles. It will be seen that considerable progress has been made toward the completion of the great topographical map, on a scale of one inch to eight miles, that will embrace an approximate area of 1,443,360 square miles; or an area considerably larger than that embraced by all the States lying east of the Mississippi River.

STATISTICS OF EXCHANGES.

BOXES SENT ABROAD IN 1877.

Country.	Smithsonian exchanges.	Government exchanges.		Total.
		No. of boxes.	Mark.	
AFRICA.				
Algiers, per France				
Cape Colonies, per England				
Egypt	2			2
Mauritius, per England				
St. Helena, per England				
AMERICA.				
Argentine Confederation	4	5	G. H. I.	9
Brazil	7	2	H. I.	9
Canada	1	4	H. I.	5
Chili		2	H. I.	2
Costa Rica	1			1
Cuba	1			1
Guatemala	1			1
Hayti		3	G. H. I.	3
Mexico	3	2	H. I.	5
Nicaragua	2			2
United States of Colombia	1			1
Venezuela	1	3	G. H. I.	4
West Indies	1			1
ASIA.				
China, per England				
East Indies, per England				
Japan	9	2	H. I.	11
Java, per Holland				
Philippine Islands, per Spain				
AUSTRALIA.				
New South Wales	4	2	H. I.	6
New Zealand	7	2	H. I.	9
Queensland	1	2	H. I.	3
South Australia	2	2	H. I.	4
Tasmania	2	2	H. I.	4
Victoria	5	2	H. I.	7
EUROPE.				
Belgium	4	2	H. I.	6
Denmark	5			5
France	29	3	G. H. I.	32
Germany	89	6	H. I.	95
Great Britain	67	4	H. I.	71
Greece		7	C. to I.	7
Holland	11	2	H. I.	13
Iceland, per Denmark				
Italy	20			20
Malta, per England				
Norway	7	2	H. I.	9
Portugal	12	2	H. I.	14
Russia	16			16
Spain	8	2	H. I.	10
Sweden	7	2	H. I.	9
Switzerland	4	2	H. I.	6
Turkey		2	H. I.	2
POLYNESIA.				
Sandwich Islands	1			1
	335	71		406

RECAPITULATION.

Africa	2			2
America	23	21		44
Asia	9	2		11
Australia	21	12		33
Europe	279	36		315
Polynesia	1			1
Total	335	71		406

NOTE.—Fifteen thousand two hundred and thirty-three miscellaneous packages, of which 100 contained specimens of natural history, exclusive of 3,500 Smithsonian publications, in all 18,733 addressed packages.

Table showing the number of entries in the record-books of the United States National Museum at the close of the years 1876 *and* 1877, *respectively.*

[These tables show only what has been recorded or entered in the detailed catalogue, constituting but a small proportion of the whole.]

Class.	1876.	1877.
Mammals	12,612	12,838
Birds	70,987	73,523
Reptiles and amphibians	8,572	9,500
Fishes	16,893	20,864
Skeletons and skulls	15,442	15,877
Eggs	17,301	17,500
Crustaceans	2,310	2,324
Annelids	100	100
Mollusks	30,721	30,721
Radiates	3,229	3,229
Invertebrate fossils	7,905	7,906
Minerals	20,050	20,135
Ethnological specimens	27,880	30,883
Total	234,002	245,400
Increase for 1877		11,398

Approximate table of the distribution of duplicate specimens to the end of 1877.

Class.	Total to the end of 1876.		Distribution during 1877.		Total to the end of 1877.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skeletons and skulls	531	1,624	5	194	536	1,818
Mammals	2,141	4,792	18	18	2,159	4,810
Birds	25,816	39,426	1,778	2,440	27,594	41,866
Reptiles	2,005	3,282	130	206	2,135	3,488
Fishes	2,984	6,222	3,156	3,423	6,140	9,645
Nests and eggs of birds	7,428	18,128	211	618	7,639	18,746
Insects	4,081	9,360	128	140	4,209	9,500
Crustaceans	1,078	2,650	9	14	1,087	2,664
Shells	89,961	195,514	210	929	90,171	196,443
Radiates	583	778	10	15	593	793
Other marine invertebrates	1,844	5,160	48	65	1,892	5,225
Plants and packages of seeds	28,450	49,855	987	1,114	29,437	50,969
Fossils	4,125	10,154	236	314	4,361	10,468
Minerals and rocks	9,083	16,824	21	44	9,104	16,868
Ethnological specimens	2,065	2,481	169	200	2,234	2,681
Diatomaceous earths (packages)	408	1,162	20	20	428	1,182
Total	182,583	367,412	7,136	9,754	189,719	377,166

LIST OF DONATIONS TO THE NATIONAL MUSEUM IN 1877.

Alaska Commercial Company, San Francisco, Cal. Two skins of the blue fox and two of the white fox (*Vulpes lagopus*), from the Prybilov Islands, Alaska.

Ammen, Commodore Daniel, Hydrographic Office. Soundings of the United States steamer Gettysburg, on the Gorringe bank.

Anderson, W. Bones, shells, &c., from cave in Ohio.

Appleton, R. M. (through John Sutherland). Salmon-trout and white-fish, from Lake Winnipiseogee, New Hampshire.

Arnold, J. Edward. Three eggs of selachian, from Santa Monica Bay, California.

Atkins, Charles G. Collection of fishes (salmon, white-fish, suckers, &c.), from Grand Lake Stream, Maine.

Anderson, William. Box of stone implements and pottery, from Illinois.

Babcock, L. L. Skin of *Hedymeles ludovicianus*, from Massachusetts.

Baird, Prof. S. F. Three everglade kites, two boxes fishes, reptiles, shells, seven boxes turtles, fishes, &c., and potstone dish from Florida; two boxes of fishes from Wilmington, N. C.; box of fishes from Charleston, S. C.; four living terrapins from North Carolina; stone tube from Tennessee, and specimen each of *Morpho cypris* and *M. menelaus*, from South America.—See, also, *Washington*, United States Fish Commission.

Baldwin, D. Skull of black-tailed deer, and skeletons of skunks.

Ballou, W. H. Box of Indian relics, from Oak Harbor, Ohio.

Bannister, Marshall. Box of skins of Massachusetts birds.

Barber, E. A. Skin of loon, from California (collected by J. H. Buel), box of fossils, shells, and minerals, from Colorado and Arizona.

Barringer, A. L. Four boxes of living snakes, from North Carolina.

Bassett, William. Specimen each of shad and cat-fish, from the Sacramento River.

Beach, Miss Agnes. Horned toad (*Phrynosoma*), from Colorado.

Beach, Seth. Piece of enamel of tusk of mammoth.

Bean, Dr. T. H. Skin of night-jar, specimens of *Hybognathus regius*, *Pseudopleuronectes americanus*, and plaice, *Pleuronectes glaber*; frogs, (*Rana halecina* and *R. clamitans*), from Washington, D. C.; three boxes of stone implements, from Bainbridge, Pa., and stone celt, from Maryland.

Bean, Dr. T. H., & F. H. Cushing. Collection of fragmentary pottery, arrow heads, &c., from Washington, D. C.

Beardslee, Commander L. A., U. S. N. Box of salmon and trout, from Piseco Lake, New York.

Beaty, John F. Ball of matted hair taken from stomach of Texas ox.

Beauchamp, Rev. W. M. Box of stone implements and shells, from Western New York.

Beaumont, Thomas. Specimens of arrow-heads and rocks, from Kansas.
Beckwith, J. R. Devil beetle (*Dynastes*), from New Orleans, La.
Belding, L. Large collection of birds' skins, from California.
Bellinger, Edmund. Narcotic bean (Indian "Freholea"), from Texas.
Benecke, Louis. Box of minerals, from Missouri.
Bennett, Dr. Jaw of fossil *Macropus*, from Darling Downs, Queensland.
Bennett, C. J. Collection of arrow-heads and chippings, from Virginia.
Bennett, Henry B. Fragments of pottery, from near Cape Henlopen.
Berlin, A. F. Collection of rude stone implements, from Pennsylvania.
Bernays, Dr. F. T. Echinoderm, from Missouri.
Binney, W. G. Seven species of *Helices*.
Bishop, J. N. Box of 17-year locust and box of minerals, from Connecticut.
Blackford, Eugene G. Specimens of blue-back trout, suckers, *Cristivomer namaycush*, *Salmo salar*, *Coregonus albus*, *Lota lacustris*, *Alepidosaurus ferox*, *Argyrosomus tullibee*, smelt, *Esox nobilior*, *Lachnolæmus*, *Ostracion*, shad, Bermudian prawn, oyster shells, and many other species of fishes, from various localities in the United States.
Bland, Thomas. Nine species of *Helices*.
Boardman, Geo. A. Egg of *Aramus giganteus*; mounted skin of albino robin from Maine; skins of blue heron and hawk, from Florida.
Boehmer, Geo. H. Nest and 4 eggs of crow, from Maryland.
Bowers, Rev. Stephen. Forty-four boxes of ethnological collections, from Santa Barbara, Cal.
Boyd, Dr. S. B. Shed skin of black snake.
Brackett, Col. A. G., U. S. A. Box of birds' skins and eggs, from Wyoming.
Bransford, Dr. John F., U. S. N. Thirty-five boxes of pottery and tank of alcoholics, from Nicaragua.
Brazilian Commission, Philadelphia. Specimens of glue, marine grasses, &c.
Brodnax, Benj. H. Indian utensils, and iron dust, from Plantersville La.
Brown, A. Centipede and tarantula, from Texas.
Brown, Dr. J. J. Box of *Pupas*, *Helices*, &c., from Bermuda; specimen of *Chrosomus erythrogaster*, from the Baraboo River, Wisconsin.
Bruner, C. C. Box of invertebrate fossils, from the Mississippi.
Bunting, Gen. T. B. Two stone idols, from Guatemala.
Butler, A. W. Skin of *Regulus calendula*, from Indiana.
Carley, B. J. M. Specimen of borer-clam, and box of Calcutta oysters.
Carpenter, Lieut. W. L., U. S. A. Box of birds' eggs, from the West.
Case, H. B. Casts of stone implements, from Ohio.
Casey, Edward P. Carved black-slate dish, from the northwest coast.
Catlin, J. C. Insect, from Ohio.
Centennial Board of Finance, Philadelphia. The Swedish exhibit of iron and steel at the Vienna Exposition of 1873.

Chapman, N. A. Stone implements, from Ohio.
Chase, Orem M. Specimen of *Lota lacustris*, from Detroit, Mich.
Chester, Capt. H. C. Stomachs of mackerel, from Fisher's Island Sound
Clark, Geo. A. Spider, from Washington, D. C.
Cleneay, Thomas. Collection of stone implements, from Ohio.
Coggswell, Amos. Specimen of silver ore, from Oregon.
Coleman, George. S. Specimen of coal, from Texas.
Colvin, Verplanck. Specimens of white-fish and salmon, from Raquette and Bisby Lakes, New York.
Coues, Dr. Elliott., U. S. A. Five skins of birds, from Wyoming and Dakota.
Coulter, R. M. Crustacean (*Branchipus*), from Ohio.
Coup, W. C., New York Aquarium. Flying-fox (*Pteropus*); and Mexican *Axolotl*, from Germany.
Courtenay, William. Insects, from Dakota.
Cruger, Kortwright. Fresh-water polyp.
Cunningham, K. M. C. See Gaines.
Cushing, Frank H. and Henry J. Biddle. Three boxes of cave remains, from Hagerstown, Md.
Cheney, S. F. Star-fish and specimens of coral, from Grand Manan, N. B.
Daggett, P. Rocks and minerals, from Vermont.
Day, Robert. Two fish (*Cyprinodonts*).
De Beck, D. W. Collection of fossils.
Derry, C. W. Box of silver ores, from the "J. D. Dana" Ledge, Danaville, Colo.
Dimock, W. D. Stone implement, from Ohio.
Doron, T. S. Specimens of fishes, from the Alabama River.
Doughertyville, Tenn., Quarry Company. Slab of marble.
Downing, S. W. Sulphate of soda, in deposit and solution.
Duffy, Daniel J. Specimens of *Dorosoma* and *Hyodon*, from the Tennessee River.
Duges, Dr. Don Alfredo. Box of birds' skins, from Mexico.
Dunn, Geo. H. Casts of stone implements and images, from Indiana and Ohio.
Dunn Brothers, Philadelphia. Three boxes of China clays.
Du Pre, D. A. Box of fossil plants, from Virginia.
Dickinson, E. Specimens of birds' eggs, from Palestine, and nest and eggs of *Selasophorus alleni*, from California.
Easton, D. M. Specimens of quartz, from New Mexico.
Edwards, Vinal N. Thirteen boxes of fishes, from Wood's Holl, Massachusetts.
Elliott, B. S. Bone from round of beef with circular rings.
Ellsworth, E. W. Collection of shells and wooden implements, from Connecticut.
Eversfield, Dr. W. O. Drilled ceremonial implement from Maryland.
Ferguson, S. W. Live snapping turtle and specimens of pike-perch, from the Mississippi River.

Fisher, Miss ———. Collection of English mosses.
Flack, J. O. Specimen of ore, from Fort Smith, Ark.
Fogg, W. H. Specimen of fossil (*Allorisma*), from Indiana.
Ford, John. Stone implement, from Illinois.
Ford, J. B. Quartz pebble.
Forney, D. S. Specimen of magnetic iron, from Virginia.
Fox, W. H. Thirteen bird's skins, from New Hampshire.
Frink, W. R. Specimen of sounding sand, from Kania, Hawaii.
Frith, David R. Native Carib chairs, from Turk's Island, West Indies.
Fuller, Capt. Joseph J. Collection of fishes, birds and mammals, from Kerguelen Land, S. A.
Fitzhugh, D. A. Specimens of *Notemigonus chrysoleucas*, from Bay City, Mich.
Gabb, Dr. W. M. Two wooden idols and box of alcoholics, from St. Domingo; one Carib wooden chair, two wooden Carib carvings.
Gaines, Maj. A. S. & K. M. Cunningham. Two boxes of pottery, from Mobile, Ala.
Galbraith, F. G. Arrow points and stone implements, from Bainbridge, Pennsylvania.
Garreth, J. E. Newt in alcohol, from Pennsylvania.
Garland, Maurice H. Red-tailed hawk (*Buteo borealis*), from Virginia.
Gibbs, Geo. J. Corals, ball of matted hair from stomach of cow, seeds of giant yellow stramonium, and stone relics, from Turk's Island, W. I.
Gill, Mrs. Charlotte. Insects, from Colorado.
Glass, Dr. J. H. Box of shells, from Oneida County, N. Y.
Goodale, S. L. Samples of Menhaden oil and *extractum carnis.*
Goode, G. Brown. Collections of fishes, shells, coral, twenty-two eggs of *Phaeton flavicauda*, and fish-trap (model), from Bermuda; specimen of salmon, from the Connecticut River.
Gordon, J. J. Specimen of coal, from West Virginia.
Graham, J. B. Model of fish-weir.
Grant, General U. S. Bust of General Grant executed in wire, exhibited by the Peruvian section, International Exhibition, 1876.
Greegor, I. Collection of Indian relics, from Florida.
Gregg, A. Photograph of sternum of deer.
Griest, Jesse W., United States Indian agent. Specimen of mineral, from Otoe agency, Nebraska.
Gundlach, Dr. Juan. Ten specimens of birds' skins, from the West Indies.
Haldeman, Dr. S. S. Indian slung-shot and plume, collected by Lewis and Clarke expedition.
Hall, M. E. Fresh and alcoholic specimens of herring, from Lake Champlain.
Hall, Capt. W. G. Basket, ceremonial ax, and collection of shells, from the South Sea Islands.

Haller, Chris. D. Albino robin, in flesh, from Virginia.
Hallock, Charles. Collection of alcoholic fishes.
Hammons, S. C. Minerals, from Alabama.
Hardenburgh, A. R., United States surveyor-general, California. Specimens of gold, silver, and other ores from various mines in California.
Haskin, S. D. Lydite, celt, and double-grooved stone ax, from Tennessee.
Harman, A. G. Broken arrow-head.
Hayward, F. W. Collection of sirens, from South Carolina.
Hessel, Rudolph. Specimen of *Astacus fluviatilis*, from Bohemia.
Hewitt, H. N. Specimen of pike.
Hewitt, John R. Entozoic worm, from liver of cat.
Hilder, Fred. F. Collection of mound pottery, from Missouri.
Hill, Charlotte. Fossil insects and leaves, from Colorado.
Hill, H. H. Casts of stone implements, from Ohio.
Himes, Prof. Chas. F. Bones, from cave near Hagerstown, Md.
Hirst, F. Collections of fossil shells, bones, fishes, Indian stone implements and pottery, birds' eggs and skins, fishes and worms, and skull of *Castor fiber*, from Wyoming.
Hitchcock, H. N. Skin of *Plectrophanes maccowni*, from Arizona, and skin of Louisiana tanager, from California.
Hoffman, Dr. W. J., U. S. A. Album of autobiographical pictures, by "Running Antelope," a Dakota Indian chief.
Holden, Captain. Snake, from Indianola, Tex.
Hubbard, S. jr. Box of California birds' eggs.
Hulbert, Robert H. Specimen of fish (*Chimæra plumbea*), from the La Have banks.
Illig, H. L. Box of stone implements, from Lebanon County, Pennsylvania.
Irwin, Dr. B. J. D., U. S. A. Specimens of 17-year locust, from New York.
Ives, Frank. Box of fossils, from Kenyon County, Minnesota.
Jackson, E. E. Penis of Lacertian and specimens of gold-fish, from South Carolina.
James, Dr. T. H. Box of Indian relics, from Arkansas.
Janeway, Dr. J. H., U. S. A. Three bottles of fishes, from Saint Augustine, Fla.
Jeffries, W. W. Collection of rocks, from Pennsylvania.
Jennings, R. G. Eggs of tarantula, from Arkansas.
Jewett, Colonel. Bottle of parasites (*Cymothoids*), from Santa Barbara, Cal.
Johnson, W. R. Mineral, from Marion County, Virginia.
Jones, H. R. Stone pipe and arrow-heads, from Indiana.
Jones, W. Mineral earth, from Alabama.
Jordan, Prof. D. S. Collection of western and southern fresh-water fishes.

Kales, J. W. Indian stone tube, from Ohio.

Keep, Professor. ————————

Kendrick, Frank F. Specimen of coal, from Virginia.

Kercheval, A. W. Quartz crystals, from West Virginia.

Kershaw, John. Box of fossils, from Nebraska.

Klemm, Theodore. Swan, in flesh, from Maumee Bay, Ohio.

Kohn, G. Collection of turtles and salamander (*Manculus 4-digitatus*), from Louisiana.

Krefft, Gerard. Specimens of *Eleotris*, perch, and *Phascogale*, from Queensland, Australia.

Kumlien, A. L. Collection of birds' skins, from Wisconsin; nest and eggs of *Zonotrichia coronata*, from California.

Langdon, Frank W. Collection of birds' skins, from Ohio.

Langley, William E. Crab, from New South Wales, Australia.

Lawrence, Alfred N. Skeleton of cow-fish (*Tursiops*), from Rockaway Beach, Long Island.

Le Baron J. F. Box of shells, bones, pottery, &c., from Florida.

Letton, Rev. J. E. Insect (*Lampyris*), from Kentucky.

Locke, William M. Boxes of stone implements, from Ohio and New York.

Lockwood, Samuel. Prepared skeletons of bass and shad.

Loomis, W. T. Two frost-fish (*Coregonus*), from White Lake, New York.

Love, Dr. J. G. Two marine shells.

Lugger, Otto. Specimens of *Umbra pygmæa*, *Parephippus faber*, *Gobiids*, &c., and shark (*Ginglymostoma cirrhatum*), from Chesapeake Bay.

Lyford, W. H. Portion of lower jaw of musk-rat.

McAdoo, Col. W. G. Box of pottery, from Georgia.

McGannis, A. Specimens of mineral, from California.

McGregor (Iowa) Artesian Well Company. Bottle of artesian-well water.

McKinley, Wm. Box of Indian relics and funeral urn, from Georgia.

McLeod, R. R. Black fox in flesh, from Maine.

McNeill, Alexander. Specimen of sand impregnated with asphaltum.

McWilliams, Dr. Skin of *Carpodacus hæmorrhous*, from Mexico.

Mahrenholz, H. & A. Tanned skin of breast of human being.

Marsh, H. N. Quartz pebble, from New Jersey.

Martin, F. H. Skin each of *Dendroica coronata* and *D. laburniæ*, from New Hampshire.

Mason, Prof. O. T. Fossil fish, from California.

Mather, Fred. Eggs of *Urophycis regius* and parasites from *Menobranchus lateralis.*

Matteson, F. S. Skin of cinnamon bear and skin of cuckoo (*Coccyzus americanus*), from Oregon.

Maxson, O. P. Salmon, from Lake Michigan.

Maynard, C. J. Skin of *Passerculus princeps*, from Massachusetts.

Mazyck, W. G. Box of alcoholic specimens of mollusks, from South Carolina.

Meigs, Henry. Two boxes of antiquities, from Bolivia.

Meigs, General M. C., U. S. A. Rat, in flesh.

Meldrum, George. Collection of Indian relics, from Ohio.

Mercer, R. W. Supposed cremated remains from Indian vase.

Merrill, Mr. (through J. Henderson.) Chipped arrow-points, from Illinois.

Merrill, Dr. J. C., U. S. A. Three boxes of birds' skins, two boxes of general natural-history collections, skin of *Felis yaguarundi*, from Texas.

Mickleborough, John. Collection of Lower Silurian fossils, from Ohio.

Middleton, E. J. Thirty-six birds' and one weasel's skin.

Miller, Howard. Dried plant, from Pennsylvania.

Mills, Clark. Sixty-four casts of heads of Indians, from Florida.

Milner, J. W. One box general natural history, 1 keg of alcoholics, 5 living turtles, box of fishes, from Havre de Grace, Md.; 1 black bass, box of stone implements, from Illinois.

Minnieville Mining Company, New York. Specimens of iron ore.

Moore, N. B. Four birds' skins, from Nassau, N. P., West Indies.

Morgan, Senator John T. (through Interior Department). Mica, from Alexander City, Ala.

Mueller, Dr. Rudolph. Stone celts, from Ohio, and moccasins, from "Custer's battle-field."

Murphy, W. M. Jaws of *Haploidonotus grunniens.*

Nash, J. C. Brass hose-nozzle, from mound, in West Virginia.

National Museum of Mexico. Collection of Mexican ethnologica and birds.

Neff, Peter. Cast of stone face.

Nelson, E. W. Skin of wild cat (*Lynx rufus*), from California; collection of fishes from the Illinois and Calumet Rivers; collection of ethnologica and general natural history, from Saint Michael's, Alaska.

Newton, H. Three boxes of fossils, from the Black Hills.

Nichols, Dr. C. H. Specimens in flesh of peacock and Canada goose.

Norway, King of. Two native chairs.

Nottingham, Wm. Specimen of *Inoceramus*, from Washington, D. C.

Nye, Willard. Box of alcoholic fishes, from New Bedford, Mass.

Ober, F. A. Collection of birds, mammals, reptiles, and fishes, from Dominica; and box of general natural history, from the Bahamas, West Indies.

Ogle, David G. Collection of rocks, fossils, and Indian relics, from Maryland.

Ordnance Department, U. S. A., Gen. S. V. Benét. Large collection of general natural history, fossils, minerals, and Indian implements, from the West.

Osgood, F. Story. Minerals, from Massachusetts.

Outerbridge, A. E., jr. Microscopic slide of gold, from the United States Mint, Philadelphia.

Owingo, Mr. Ironstone nodule.

Palmer, Joseph. Skeleton each of horse and duck.

Palmer, William. Collection of fishes, from the Potomac River; snakes, from Virginia and Maryland.

Peeler, Henry A. Caterpillar, from New Orleans.

Pergande, Ph. Collection of eggs, bones, woods, &c., from Missouri.

Permanent Exhibition Company, Philadelphia. New South Wales', Victoria's, and Carneghy's exhibits of minerals.

Perrine, T. M. Box of stone implements, from Illinois.

Plummer, Miss S. A. Can of mollusks, from California.

Powel, Samuel. Two tanks, 1 box, and 1 keg of fishes, from Newport, R. I.

Preston, D. A. Box of minerals, from Joplin, Mo.

Queensland, Australia, Acclimatization Society. Package of seeds of *Maba fasciculosa* and photographs of aborigines of Australia.

Ramsey, N. A. Specimen of kaolin, from North Carolina.

Rau, Dr. Charles. Indian stone tube, from Warren County, Kentucky.

Ravenel, H. W. Bermuda grass, from Aiken, S. C.

Redding, B. B. Fishes and invertebrates, from Japan; specimens each of awa (*Chanos salmoneus*) and mullet (*Mugil chaptalia*), from Honolulu.

Reeder, H. J. California salmon (*Salmo salar*), from the Delaware River.

Reid, Dr. J. H. Two Indian mallets and arrowhead, from Colorado.

Reinsch, Dr. P. F. Box of microscopic slides of meteoric stones.

Reis, Prof. J. B., Centennial Commissioner. Portuguese arboretum, specimens of cottons from African and Indian colonies, books, photographs, &c.

Republic (the) Iron Company, David Morgan, President. Specimens of red specular iron-ore.

Reville, Father D. Anal spines and interspinal bones of sheep'shead.

Reynolds, Hon. A. R., Minister to Bolivia. Box of copper ores, from Bolivia.

Richard, J. H. Thirty-one turtles, 1 frog, and 12 shells, from Pennsylvania.

Richmond, A. G. Small package of fragmentary pottery, from New York.

Ridgway, Robert. Box of birds, reptiles, &c., from Mount Carmel, Ill.; 2 birds, nest and eggs, from Washington, D. C.

Robertson, R. S. Two stone implements and portions of human crania, from Illinois.

Robertson, Dr. W. B. Specimens of *Campostoma*, from Holstein River, Virginia.

Robinson, Neill. Stone celt from West Virginia.

Rosamond, W. B. Box of stone implements, from Ohio.

Rust, H. N. Box of mound pottery, from Illinois.

Samuels, S. B. Minerals, from Virginia.

Schneck, J. Bottle of spiders, from Illinois.

Seligman, Henry, & Co. Sample of stable-purifying compound.

Sellers, G. E. Box of pottery and stone implements, from Illinois.

Shaffer, David H. Box of *Unios*, from Little Miami River, Ohio.

Sharp, S. Z. Box of fresh-water shells, from the Holstein River, Tennessee.

Sharp, R. Bowlder. Nine species of Old World birds.

Shaver, Amanda B. Geological specimens, from the Ohio River bottom.

Shelby, Dr. D. Stone bowl, from Jackson County, Alabama.

Sherman, N. A. Collection of bird eggs.

Shorne, Mr., through T. B. Ferguson. Section model of oyster pungy.

Slingerland, A. Stone implement, from Missouri.

Smith, J. P. Arrowheads, from Maryland.

Small, E. E. Two grampuses, from Highland light, Massachusetts.

Smith, Frank. Collection birds' eggs.

Smith, W. H. Gall insects, from Chapel Hill, N. C.

Snyder, S. P. Specimens of galena, from Wyoming Valley, Pennsylvania.

Sonnanstine, J. F. Supposed Indian implement, from Ohio.

Southwell, J. H. Bone perforator, from Illinois.

Spangler, Geo. Box of fossils, from Indiana.

Spanish Legation, Washington. Collection of Spanish pottery.

Stabler, James P. Snake (*Ophibolus triangulus*), from Maryland.

Stearns, R. E. C. Stone implements and Indian food, from California.

Sterling, Dr. E. Cast of ovaries of fish, and dwarf pike (*Esox pygmæus.*)

Stone, Gen. Chas. P. Block of Egyptian marble.

Stone, Livingston. Collection of salmonidæ, from the Clackamas River, Oregon; box of fishes, from the McCloud River, California.

Stout, Mrs. Georgia. Box of Indian relics, from Pima Agency, Arizona.

Sutro, Adolf. Papier-maché models of the Sutro Tunnel and Comstock Lode.

Taggart, R. F. Tooth of *Equus occidentalis*, from West Virginia.

Talbut, William. Living snake, from Washington, D. C.

Tanaka, Hon. Fusimaro. Collection of Japanese coins.

Tasmania, Government of. Two specimens of *Platypus* and three of *Echidnæ;* three boxes of seeds of Australian plants.

Tate, Geo. K. Specimen of iron pyrites, from North Carolina.

Thomas, Hilton. Orange infested with insects.

Thomson, J. H. Chub-sucker (*Erimyzon oblongus*), *Paratractus pisquetos*, and *Achirus lineatus*, from Massachusetts.

Thomas, Pack. Shad (*Alosa sapidissima*), from the Ohio River.

Thompson, J. B. Five specimens of *Salmo quinnat*, reared from eggs planted in 1874 and 1875.

Thornburgh, Hon. J. M. Fossil coal plant, from Anderson County, Tennessee.

Thornton, S. C. Skin of common myna (*Acridotherus tristis*).

Tilghman, Dr. Chas. H. Seeds and shells, from craw of red-head duck.

Tingley, Prof. Joseph. Fossils, from Indiana.

Tokio, Japan, Museum of, Hon.———Kubo, in charge. Collection of woods and stone implements, from Japan.

Toner, Dr. J. M. Stone pipe, arrowheads, and unfinished tube, from Ohio and Kentucky; stone pestle, from Maryland.

Turner, Granville. Specimen of belemite, from the Black Hills.

Turner, Lucien M. Eight boxes of ethnologica and general natural history, Saint Michael's, Alaska.

Ull, Henry I. Box of botanical specimens, from New Jersey.

Valentine, G. G. Box of stone implements, from Virginia.

Van Benschoten, Prof. J. C. Stone ceremonial implement, from mound in Indiana.

Van Dyck, W. T. Skin of *Pastor*, from Beirut, Syria.

Vickers, J. P. Stone implement, from Illinois.

Washington, D. C.:

Department of State. See under the name of *Hon. A. R. Reynolds, minister to Bolivia.*

Treasury Department. Box of building stones, from new custom-house, Chicago, Ill.

United States Coast Survey (Capt. C. P. Patterson, in charge). Specimens of starfish, from off Cape Cod, Mass.

War Department:

United States Army. See under the names of *Col. A. G. Brackett, Lieut. W. L. Carpenter, Gen. M. C. Meigs,* and *Lieut. Willis Wittich.*

Surgeon-General's Office. See under the names of *Drs. Elliott Coues, B. J. D. Irwin, J. H. Janeway,* and *J. C. Merrill.*

Survey west of the one hundredth meridian (Lieut. G. M. Wheeler, in charge). Collection of west-coast fishes, 941 birds' skins, and 2 bales of ethnologica, from the West.

Signal Service. See under the names of *Sergeants E. W. Nelson* and *L. M. Turner.*

Navy Department:

United States Navy. See under the name of *Commander L. A. Beardslee.*

Bureau of Navigation, Commodore Daniel Ammen. Soundings, from the Gorringe bank, by the United States steamer Gettysburg.

Medical Bureau. See under the name of *Dr. J. F. Bransford.*

Interior Department:

General Land Office. See under the names of *Surveyors-General A. R. Hardenburgh* and *John Wasson.*

Indian Bureau. See under the name of Indian Agent *Jesse W. Griest.*

United States Geological Survey of the Territories, First Division, (Dr. F. V. Hayden, in charge). Five boxes and 2 tanks general natural history collections, from the West; 9 models of cliff-houses and relief maps.

United States Geological Survey of the Territories, Second Division (Prof. J. W. Powell, in charge). Eleven pieces of Shoshone Indian clothing, 1 box ethnologica. See also under the name of *Rev. Stephen Bowers.*

Washington, D. C.:

United States Fish Commission (*Prof. S. F. Baird, Commissioner*). Eleven boxes, 4 tanks marine zoölogy, collected at Wood's Holl, Salem, Mass., and at Halifax, N. S. See also under the names of *Chas. G. Atkins*, *S. F. Baird*, *T. H. Bean*, *H. C. Chester*, *Vinal N. Edwards*, *Rudolph Hessel*, *A. L. Kumlien*, *J. W. Milner*, and *Livingston Stone*.

Wall, John P. Two stone sinkers, from Florida.

Wasson, Hon. John United States surveyor-general, arizona. Specimens of gold and silver ores, from various mining claims in Arizona.

Way, D. S. Living diamond rattlesnake, from Florida.

Webb, John S. Fossils, from near Dayton, Ohio.

Werner, W. H. Skin of solitary sandpiper, from Pennsylvania.

Whitman, G. P. Marine fern (*Pennatula phosphorea* var. *aculeata*), from Brown's Bank, Mass.

Whittlesey, Charles. Cast of stone implements, from Ohio.

Willets, Joseph C. Trolling-hook used for lake-trout, at Skaneateles, N. Y.; 14 bottles of Forida fishes.

Willird, Mrs. Celeste. Box of insects, from Florida.

Williams, C. Foster. Shell, *Pyrula*, from Tennessee.

Williams, Dr. M. Specimen in flesh of Mexican flycatcher.

Williamson, J. M. Specimens of fulgurite, from Illinois.

Williamson, T. Spawn of black bass.

Wilmot, Samuel. Specimen of *Dorosoma heterura*, from Lake Huron; stuffed skin of Ontario salmon.

Winchell, Prof. Alex. Collection of fresh-water fishes, from Tennessee.

Wittich, Lieut. Willis, U. S. A. Collection of shrews, reptiles, and insects, from Fort Klamath, Oreg.

Wood, Thomas. Collection of fossils, from Maryland.

Wooster, A. F. Collections of general natural history and Indian relics, from Connecticut.

Yarrow, Dr. H. C. Box of slugs, from Washington, D. C.; box of shells (*Hydatina*), from Santa Barbara, Cal.

Yerkes, Isaac. Two celts and quartz crystal, from Pennsylvania.

Younglove, John E. Pentramites, from Bowling Green, Ky.

Yunck, John A. Sample of glass wool.

Unknown. Two boxes alchoholic birds' skins; cast of human face; 2 grooved celts; pair of moccasins and belt; 3 pieces of rock; specimens mica and granite; larvæ of migratory grasshopper.

LIST OF THE MORE IMPORTANT EXPLORATIONS AND EXPEDITIONS, THE COLLECTIONS OF WHICH HAVE CONSTITUTED THE PRINCIPAL SOURCES OF SUPPLY TO THE NATIONAL MUSEUM, WITH INDICATION OF THE DEPARTMENT OF THE GOVERNMENT UNDER WHICH PROSECUTED.

[Where no department is mentioned it is to be understood that the collections were made more especially at the request and under the direction of the Smithsonian Institution and to a greater or less degree at its expense.]

Prior to 1850.

1. *Captain Wilkes, U. S. N.* The coasts of South America, Western North America, Polynesia, etc. 1838–1842. United States Navy Department.
2. *Rev. Dr. Gurley.* West Africa. 1846–1857.
3. *Rev. C. W. Dennison.* British Guiana. 1842–1857.

1850.

4. *Dr. D. D. Owen.* United States Geological Survey made in Iowa, Illinois, and Minnesota. 1850–1857. United States General Land Office.
5. *Capts. L. Sitgreaves and J. C. Woodruff, U. S. A.* The survey of the Creek boundary. War Department.
6. *Dr. J. Evans.* United States Geological Survey of Oregon and Washington Territories. Land Office.
7. *Dr. Charles T. Jackson.* United States Geological Survey of Lake Superior. Land Office.
8. *Messrs. J. W. Foster and J. D. Whitney.* United States Geological Survey of Lake Superior. Land Office.
9. *W. Stimpson.* The New England coast.
10. *Thaddeus Culbertson.* Upper Missouri.

1851.

11. *Col. J. D. Graham and Maj. W. H. Emory, U. S. A.* United States and Mexican Boundary Survey. 1851–1855. Interior Department.
12. *Capt. L. Sitgreaves, U. S. A.* Zuni and Colorado Rivers. War Department.
13. *Capt. Howard Stansbury, U. S. A.* The Valley of the Great Salt Lake, Utah. War Department.

1852.

14. *Lieut. J. M. Gilliss, U. S. N.* United States Astronomical Expedition to Chili. 1849–1852. Navy Department.
15. *Lieut. W. L. Herndon, U. S. N.* The Amazon and its tributaries. Navy Department.
16. *Capt. R. B. Marcy and Capt. George B. McClellan, U. S. A.* The Red River. War Department.

1853.

17. *Dr. E. K. Kane.* North Greenland.
18. *Capts. C. Ringgold and J. Rodgers, U. S. N.* Exploration of the China Seas, Behring Straits, coast of California, etc. 1853–1856. Navy Department.
19. *Gov. I. I. Stevens.* The Pacific Railroad Survey of the forty-seventh parallel. 1853–1855. War Department.
20. *Lieut. R. S. Williamson, U. S. A.* The Pacific Railroad Survey on the partial route in California. 1853–1855. War Department.
21. *Captains Gunnison and Beckwith, U. S. A.* The Pacific Railroad Survey on the thirty-eighth, thirty-ninth, and forty-first parallels. 1853–1855. War Department.
22. *Captain Whipple, U. S. A.* The Pacific Railroad Survey on the thirty-fifth parallel. 1853–1855. War Department.
23. *Lieut. J. G. Parke, U. S. A.* The Pacific Railroad Survey on the western end of the thirty-second parallel. 1853–1855. War Department.
24. *Capt. J. Pope, U. S. A.* The Pacific Railroad Survey on the eastern end of the thirty-second parallel. 1853–1855. War Department.
25. *Lieut. R. S. Williamson, U. S. A.* The Pacific Railroad Survey in California and Oregon. 1853–1855. War Department.
26. *Commodore M. C. Perry, U. S. N.* Japan. 1853–1855. State and Navy Departments.
27. *Capt. J. Pope, U. S. A.* Artesian Well Borings in the Llano Estacado. 1853–1857. War Department.
28. *Dr. George Suckley, U. S. A.* Washington and Oregon Territories. 1853–1856. War Department.
29. *Dr. J. G. Cooper.* Washington Territory, California, and Nebraska. 1853–1856. War Department.
30. *Dr. F. V. Hayden.* Upper Missouri. 1853–1855.
31. *Lieut. D. N. Couch, U. S. A.* Northern Mexico.
32. *Dr. L. Berlandier.* Northern Mexico. Collections made 1826–1851 and purchased by Lieutenant Couch.
33. *Capt. T. J. Page, U. S. N.* Paraguay. Exploration of the Parana. 1853–1855. Navy Department.
34. *R. D. Cutts.* The California coast. United States Coast Survey.
35. *Prof. S. F. Baird.* Wisconsin, Illinois, and Ohio.

1854.

36. *A. J. Vaughan.* Upper Missouri. 1854–1855.
37. *Dr. P. R. Hoy.* Wisconsin and Missouri.
38. *Robert Kennicott.* Illinois, Minnesota, and Winnipeg. 1854–1857.
39. *Capt. R. B. Marcy, U. S. A.* Brazos River.
40. *Lieut. W. P. Trowbridge, U. S. A.* The Pacific coast. 1854–1855. United States Coast Survey.

41. *Gustavus Würdemann.* Texas, Louisiana, and Florida. 1854–1858. United States Coast Survey.
42. *Rev. A. C. Barry.* Wisconsin.

1855.

43. *Prof. S. F. Baird.* Coast of New Jersey.
44. *E. Samuels.* California. 1855–1856. Boston Society of Natural History and the Smithsonian Institution.

1856.

45. *Maj. G. H. Thomas, U. S. A.* Vicinity of Fort Yuma.
46. *Lieutenant Bryan, U. S. A.* Wagon-road survey from Fort Riley to Bridger's Pass. 1856–1857. War Department.
47. *Lieut. G. K. Warren, U. S. A.* On the Upper Missouri and Yellowstone. War Department.

1857.

48. *W. M. Magraw.* South Pass wagon-road. 1857–1858. Interior Department.
49. *Capt. T. J. Page, U. S. N.* La Plata River and tributaries. Navy Department.
50. *Donald Gunn.* Red River of the North and Nelson River. Hudson's Bay Territory.
51. *John Xantus.* Fort Riley, Kans., and Fort Tejon, Cal. 1857–1858.
52. *Lieut. N. Michler, U. S. A.* Exploration of a canal route. The Isthmus of Darien. War Department.
53. *Col. J. E. Johnston, U. S. A.* Southern boundary of Kansas.
54. *J. B. Leech.* El Paso and Fort Yuma wagon-road route. Interior Department.
55. *A. Campbell.* Northwestern boundary survey. Western end. 1857–1861. State Department.
56. *Lieut. G. K. Warren, U. S. A.* The Platte River Valley. War Department.

1858.

57. *Capt. Thos. Blakiston, R. A.* The Saskatchewan.
58. *Lieut. J. C. Ives, U. S. A.* Navigation of the Colorado River. War Department.
59. *Dr. F. V. Hayden and Prof. F. B. Meek.* Kansas.
60. *Dr. F. V. Hayden.* New Jersey.

1859.

61. *Capt. J. H. Simpson, U. S. A.* Kansas, Nebraska, and Utah. War Department.
62. *F. W. Lander.* South Pass wagon-road route. Interior Department.

63. *Lieut. John Mullan, U. S. A.* Wagon-road route from Walla Walla to Fort Benton. Interior Department.
64. *Capt. W. F. Raynolds, U. S. A.* Upper Missouri and Yellowstone. War Department.
65. *Capt. J. N. Macomb, U. S. A.* San Juan and Upper Colorado. War Department.
66. *John Xantus.* Cape Saint Lucas, Lower California. United States Coast Survey.
67. *John Feilner.* Fort Crook, California.
68. *Robert Kennicott.* British North America into the Arctic Circle. 1859–1861.
69. *J. W. Tolman.* Illinois.
70. *Dr. J. B. Bean.* Central Florida.
71. *Dr. Suckley, U. S. A.* Kansas, Nebraska, and Utah.
72. *William Cooper.* Bahamas.
73. *Dr. H. Bryant.* Bahamas.
74. *Dr. J. G. Cooper.* South Florida.
75. *Capt. H. G. Wright, U. S. A.* Tortugas.
76. *Capt. D. P. Woodbury, U. S. A.* Tortugas.
77. *Dr. Whitehurst.* Tortugas.
78. *Saint Charles College.* Louisiana.
79. *James McLeannan.* Isthmus of Panama.
80. *Theodore Gill.* West Indies and Newfoundland.

1860.

81. *Dr. J. G. Cooper.* To Oregon *via* Fort Benton. War Department.
82. *Capt. C. P. Stone, U. S. A.* The Gulf of California.
83. *Dr. C. S. Canfield.* The coast of California.
84. *B. R. Ross.* Mackenzie's River district. Fort Simpson, Hudson's Bay Territory. 1860–1861.
85. *George Barnston.* North shore of Lake Superior.
86. *J. Mackenzie.* Moose factory, Hudson's Bay. 1860–1863.
87. *C. Drexler.* In James Bay, Hudson's Bay.
88. *Elliott Coues.* The coast of Labrador.
89. *Williams College Lyceum of Natural History.* Greenland and Labrador.
90. *Dr. W. Stimpson.* The coast of North Carolina.
91. *Theodore Gill.* The coast of North Carolina.
92. *Dr. W. W. Anderson.* Cantonment Burgwyn, N. Mex., and on the Pecos.
93. *J. H. Clark.* The Texas boundary survey. Interior Department.
94. *J. W. Swan.* Puget Sound. 1860–1877.
95. *Dr. J. B. Holder.* Tortugas.
96. *Charles Wright.* Cuba. 1860–1863.
97. *J. M. Woodworth.* Minnesota.
98. *Patrick Duffy.* New Mexico.

99. *W. A. Henry.* Labrador Eclipse Expedition.
100. *Lieut. J. D. Kurtz, U. S. A.* On the Atlantic coast of the United States.
101. *F. Germain.* Chili.
102. *P. S. Dodd.* Sable Island, Nova Scotia.
103. *J. R. Willis.* Nova Scotia.
104. *W. G. Winton.* Nova Scotia.

1861.

105. *John Xantus.* Cape Saint Lucas and the Gulf of California. United States Coast Survey.
106. *Robert Kennicott.* Hudson's Bay Territory: Fort Resolution, Peel's River, and Fort Yukon.
107. *Lawrence Clark, jr.* Hudson's Bay Territory: Fort Rae and Great Slave Lake.

1862.

108. *John Xantus.* Western Mexico in the vicinity of Colima and Manzanillo. 1862–1863. State Department.

1863.

109. *Henry Connolly.* Hudson's Bay Territory: Rigollet, Labrador. 1863–1866.
110. *Hon. C. R. Riotte, United States minister.* Costa Rica.
111. *J. Carmiol.* Costa Rica.
112. *Dr. Charles Sartorius.* Eastern Mexico.
113. *Prof. F. Sumichrast.* Orizaba, Mexico.
114. *Capt. John. M. Dow.* West coast of Central America.
115. *Hon. C. R. Buckalew, United States minister.* Ecuador.
116. *Dr. Elliott Coues, U. S. A.* Arizona.
117. *Dr. R. Hitz.* Upper Missouri.
118. *Capt. John Feilner, U. S. A.* Upper Missouri.

1864.

119. *Col. A. J. Grayson.* Vicinity of Mazatlan, including the Tres Marias and the Revillagigedo Islands.
120. *Dr. Arthur Schott.* Yucatan, under the auspices of the government of the province.
121. *Hon. D. K. Cartter.* Bolivia.
122. *W. T. March.* Jamaica.
123. *N. H. Bishop.* Cuba.
124. *Lieutenant Fitzgerald, British Army.* New Providence, Bahamas.

1865.

125. *Gov. William McTavish.* Vicinity of Fort Garry.
126. *Robert Kennicott.* Alaska and British Columbia.

127. *Dr. H. Berendt.* British Honduras and the interior of Guatemala.
128. *Robert Swift.* Saint Thomas and Porto Rico.
129. *George Latimer.* Porto Rico.
130. *Rev. H. B. Tristram.* Palestine.

1866.

131. *C. P. Gaudet.* Hudson's Bay Territory: Fort Good Hope.
132. *William L. Hardesty.* Hudson's Bay Territory: Fort Simpson.
133. *Strachan Jones.* Hudson's Bay Territory: Vicinity of Fort Rae.
134. *James Lockhart.* Hudson's Bay Territory: Fort Resolution, Fort Yukon.
135. *John Reid.* Hudson's Bay Territory: Big Island, Great Slave Lake.
136. *James Sibbiston.* Hudson's Bay Territory: Fort Yukon.
137. *Donald Gunn.* West of Lake Winnipeg.
138. *George A. Smith.* Hudson's Bay Territory and Labrador.
139. *Robert MacFarlane.* Hudson's Bay Territory: Vicinity of Fort Anderson, Arctic Coast. 1860–1868.
140. *William Bross.* Hudson's Bay Territory: Fort Halkett.
141. *Thomas Flett.* Hudson's Bay Territory: La Pierre's House.
142. *C. L. Bulkley.* Russian America. Western Union Telegraph Company.
143. *William H. Dall.* Shores of Behring Straits. Western Union Telegraph Company.
144. *Ferdinand Bischoff.* Kodiak, Sitka, and other portions of Alaska. Western Union Telegraph Company.
145. *H. M. Bannister.* Vicinity of Saint Michael's, Norton Sound. Western Union Telegraph Company.
146. *Dr. J. T. Rothrock.* British Columbia. Western Union Telegraph Company.
147. *Dr. C. A. Canfield.* Monterey, Cal.
148. *Dr. Edward Palmer.* Arizona.
149. *Dr. Wernick.* Colorado.
150. *Dr. H. B. Butcher.* Laredo, Rio Grande.
151. *A. E. Younglove.* Hayti.
152. *Dr. Henry Bryant.* Porto Rico and the Bahamas.
153. *Henry Hague.* Guatemala.
154. *Dr. Earl Flint.* Nicaragua. 1866–1877.
155. *Dr. A. Von Frantzius and J. C. Zeledon.* Costa Rica.
156. *J. and T. Rhodes.* Panama.
157. *Valdimir Knudsen.* Sandwich Islands.
158. *William H. Hudson.* Buenos Ayres. 1866–1868.

1867.

159. *Hon. A. A. Burton.* Columbia.
160. *Ferdinand Bischoff.* Vicinity of Mazatlan.

161. *Bernard R. Ross.* Hudson's Bay Territory: Moose Factory.
162. *Prof. F. V. Hayden.* Geological Survey of Nebraska. United States General Land Office.
163. *Dr. Thomas T. Miner.* Winnebago Reservation.
164. *Clarence King.* Along the line of the fortieth parallel. War Department.
165. *Dr. M. Allen.* Bermuda.
166. *Col. A. J. Grayson.* Revillagigedo Islands.
167. *Dr. Van Patten.* Guatemala.
168. *Mr. Hardemann.* San Salvador.

1868.

169. *Prof. James Orton.* Ecuador.
170. *Mr. McDougal.* Hudson's Bay Territory, Mackenzie's River district.
171. *George Davidson.* Alaska. United States Coast Survey.
172. *Dr. F. V. Hayden.* Black Hills, Laramie Plains, &c. General Land Office.
173. *J. H. Devereaux.* Tennesee and Ohio. Ethnology.
174. *Dr. Edward Palmer.* Indian Territory.

1869.

175. *Capt. C. M. Scammon.* Coast of Oregon and Alaska. United States Revenue Bureau, Treasury Department.
176. *Dr. F. V. Hayden.* Colorado and New Mexico. Interior Department.
177. *Lieut. F. M. Ring.* In the vicinity of Fort Wrangel, Alaska. Ethnology.
178. *P. Figyelmezy.* British Guiana. State Department.

1870.

179. *Prof. S. F. Baird.* In Marine Zoology, in Vineyard Sound. 1870-1875. United States Fish Commission.
180. *Dr. F. V. Hayden.* Rocky Mountains. Interior Department.

1871.

181. *Prof. J. W. Powell.* Colorado. Interior Department.
182. *Dr. F. V. Hayden.* Montana and headwaters of the Yellowstone. Interior Department.
183. *Geo. A. Boardman.* Florida and New Brunswick.
184. *Dr. H. C. Yarrow, U. S. A.* Vicinity of Fort Macon, North Carolina.
185. *Capt. Chas. Bryant.* Pribylov Islands, Behring Sea.
186. *Strachan Jones.* Hudson's Bay Territory, Lower Slave Lake Region.

1872.

187. *Prof. S. F. Baird.* Marine Zoology in the Bay of Fundy. United States Fish Commission.

188. *Dr. A. S. Packard, jr.* George's Banks, &c. United States Coast Survey and United States Fish Commission.
189. *Henry W. Elliott.* Saint Paul of the Pribylov or Fur Seal Islands of Behring Sea. Treasury Department.
190. *William H. Dall.* Alaska and the Aleutian Islands. 1872–1874. United States Coast Survey, Treasury Department.
191. *Prof. F. V. Hayden.* Basin of the Upper Yellowstone and various regions of the Rocky Mountains. Interior Department.
192. *Lieut. Geo. M. Wheeler, U. S. A.* Southern Utah and Eastern Nevada. War Department.
193. *Prof. J. W. Powell.* Colorado River. 1872–1875. Interior Department.
194. *F. Sarg.* Guatemala.
195. *Prof. William M. Gabb.* San Domingo.
196. *G. Brown Goode.* Bermuda.

1873.

197. *Capt. C. F. Hall and Dr. Emil Bessels.* In the Arctic Seas, on the Polaris. Navy Department.
198. *Henry W. Elliott.* Saint George's Island of the Pribylov Group. Treasury Department.
199. *Commodore G. E. Belknap, United States Steamer Tuscarora.* North Pacific Ocean. Navy Department.
200. *Archibald Campbell and Dr. Elliott Coues.* Along the north western boundary survey, in Dakota. State Department.
201. *Gen. David S. Stanley and J. A. Allen.* Along the line of the Northern Pacific Railroad. War Department.
202. *Prof. F. V. Hayden.* Colorado and New Mexico. Interior Department.
203. *Lieut. Geo. M. Wheeler.* The region west of the 100th meridian. War Department.
204. *Capt. Charles Bendire, U. S. A.* Arizona.
205. *Livingston Stone.* Upper Sacramento River. United States Fish Commission.
206. *James W. Milner.* The Great Lakes and the Upper Mississippi. United States Fish Commission.
207. *Prof. S. F. Baird.* Vicinity of Portland, Me. United States Fish Commission.
208. *Vinal N. Edwards.* Vicinity of Wood's Hole, Massachusetts. United States Fish Commission.
209. *Samuel Powel.* In Narraganset Bay.
210. *Prof. William M. Gabb.* Costa Rica. Government of Costa Rica.
211. *Prof. F. Poey.* Cuba.

1874.

212. *Lieut. Geo. M. Wheeler.* Nebraska, Utah, Colorado, New Mexico, and Arizona. War Department.

213. *Prof. F. V. Hayden.* West of the one hundred and seventh meridian, in Colorado. Interior Department.
214. *Prof. J. W. Powell.* Utah. 1874–1877. Interior Department.
215. *Prof. S. F. Baird.* South coast of Connecticut. United States Fish Commission.
216. *Capt. Nicholas Pike.* The Mauritius. State Department.
217. *A. B. Steinberger.* The Samoan Islands. State Department.
218. *Lucien M. Turner.* Vicinity of Saint Michael's, Norton Sound. 1874–1877. United States Signal Service, War Department.
219. *Prof. H. E. Webster.* The coast of Virginia.

1875.

220. *Prof. S. F. Baird.* Vineyard Sound and Buzzard's Bay. United States Fish Commission.
221. *Alaska Commercial Company.* The coast and islands of Alaska.
222. *Paul Schumacher.* Oregon and the mainland and islands adjacent to Santa Barbara. (Ethnology.) 1875–1876. Peabody Museum, Cambridge, and Indian Bureau, Interior Department.
223. *Rev. Stephen Bowers.* The south coast of California. (Ethnology.) 1875–1877. Indian Bureau, Interior Department.
224. *J. G. Swan.* British Columbia: Vancouver's Island, &c. Indian Bureau, Interior Department.
225. *Stephen Powers.* Nevada and California. (Ethnology.) Indian Bureau, Interior Department.
226. *Dr. J. H. Kidder, U. S. N.* Transit of Venus Expedition: Kerguelen Island and other points. Navy Department.
227. *Dr. E. Kershner, U. S. N.* South Pacific, in the United States steamer Swatara. Navy Department.
228. *Edwin Smith.* Chatham Islands. United States Coast Survey and Navy Department.
229. *Prof. F. V. Hayden.* Colorado, Northern New Mexico, and Eastern Utah. Interior Department.
230. *Lieut. Geo. M. Wheeler.* Colorado and Arizona. War Department.
231. *Dr. Edward Palmer.* Arizona and California. Indian Bureau, Interior Department.

1876.

232. *W. A. Mintzer.* Arctic America, north of Hudson's Strait. Navy Department.
233. *Dr. W. W. Hays.* San Luis Obispo. (Ethnology.)
234. *Dr. J. F. Bransford.* Nicaragua. 1876–1877. (Ethnology.) Navy Department and Peabody Museum, Cambridge.
235. *Capt. J. G. Baker.* Islands south of California. Treasury Department.
236. *Prof. F. V. Hayden.* Western Colorado and Eastern Utah. Interior Department.

1877.

237. *Prof. F. V. Hayden.* Wyoming, Idaho, and Northern Utah. Interior Department.
238. *E. W. Nelson.* Norton Sound, Alaska. United States Signal Office and Smithsonian Institution.
239. *Prof. D. S. Jordan.* Fresh waters of Southern States.
240. *Dr. J. F. Bransford, U. S. N.* Nicaragua and Costa Rica. Medical Bureau, Navy Department.
241. *Rev. Stephen Bowers.* Islands and mainland adjacent to Santa Barbara, Cal. Maj. J. W. Powell, Interior Department and Smithsonian Institution.
242. *Clark Mills.* Indians in Florida. Peabody Museum, Cambridge, and Smithsonian Institution.
243. *F. A. Ober.* West India Islands: Dominica, Antigua, Barbadoes, &c.
244. *S. F. Baird.* Coast of Massachusetts off Salem, and of Eastern Nova Scotia. United States Fish Commission.
245. *Livingston Stone.* Clackamas River, Oregon. United States Fish Commission.
246. *Capt. J. J. Fuller.* Kerguelen Island.
247. *Maj. A. S. Gaines and K. M. Cunningham.* Shell mounds near Mobile, Ala.
248. *G. B. Goode.* Bermuda and surrounding waters. Wesleyan University, Middletown, Conn., and Smithsonian Institution.

CLASSIFICATION OF THE ABOVE MENTIONED EXPLORATIONS UNDER THE DEPARTMENT BY WHICH CONDUCTED.

Smithsonian Institution: carried on directly by or under the supervision of the Institution, and for the most part wholly or partially at its expense: 87, 88, 90, 91, 94, 95, 96, 97, 98, 99, 102, 105, 106, 110, 111, 112, 113, 116, 117, 118, 119, 122, 123, 127, 128, 129, 137, 138, 139, 140, 141, 147, 148, 150, 151, 153, 154, 155, 158, 160, 163, 165, 166, 167, 173, 174, 177, 185, 196, 219, 233, 239, 243, 246.

Smithsonian Institution: less directly under the charge of the Institution, and not at its expense, but the results communicated to it: 82, 83, 92, 100, 101, 103, 104, 114, 115, 121, 124, 128, 129, 130, 149, 152, 156, 157, 159, 168, 178, 183, 184, 194, 195, 204, 209, 211, 247.

Smithsonian Institution, with the especial aid of the Hudson's Bay Company: 84, 85, 86, 107, 109, 125, 131, 132, 133, 134, 135, 136, 161, 170, 186.

Smithsonian Institution and United States Coast Survey: 105, 171, 188, 190, 228.

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REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee of the Board of Regents of the Smithsonian Institution respectfully submit the following report in relation to the funds of the Institution, the appropriations by Congress for the support of the National Museum, the receipts and expenditures for both the Institution and the Museum for the year 1877, and the estimates for the year 1878.

Statement of the condition of the funds at the beginning of the year 1878.

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States, in accordance with the act of Congress of August 10, 1846		$515,169 00
Residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of February 8, 1867		26,210 63
Total bequest of Smithson		$541,379 63
Amount deposited in the Treasury of the United States as authorized by act of Congress, February 8, 1867, derived from savings of income and increase in value of investments		108,620 37
Amount of the bequest of James Hamilton, of Carlisle, Pa., February 24, 1874		1,000 00
Total permanent Smithson fund in the United States Treasury, bearing interest at 6 per cent., payable semi-annually in gold		$651,000 00
In addition to the above, there remains of the extra fund, from savings, &c., in Virginia bonds and certificates, viz:		
Consolidated bonds	$58,700 00	
Deferred certificates	29,375 07	
Fractional certificate	50 13	
Total	88,125 20	
Valued January, 1878, at		34,562 00
Also, the cash balance deposited in the United States Treasury, at the beginning of the year 1878		25,083 90
Total Smithson funds, January 6, 1878		$710,645 90

RECEIPTS IN 1877.

Interest on $650,000, for the year 1877, at 6 per cent., gold		$39,000 00
Premium on gold interest:		
June 30, 1877, @ $5\frac{5}{16}$	$1,035 94	
January 6, 1878, @ $2\frac{11}{16}$	524 06	
	1,560 00	
Less broker's commission	48 74	
		1,511 26
Interest on Virginia bonds:		
Sale of coupons by Riggs & Co., for January 1 and July 1, 1877, for $3,522, November 26, 1877, @ 82–$82\frac{1}{2}$		2,885 76
Interest on Hamilton fund of $1,000:		
For the year 1877	$60 00	
Premium on gold, less brokerage	2 32	
		62 32
Repayment by National Museum:		
For advances made by Smithsonian Institution in 1875–'76, for International Exhibition, &c		5,548 28
Total receipts for the year 1877		$49,007 62

EXPENDITURES IN 1877.

Building, furniture and fixtures	$4,030 66	
General expenses	16,052 64	
Publications, researches and explorations	12,946 81	
International literary and scientific exchanges	9,790 73	
Gallery of art	1,710 83	
National Museum	421 23	
		44,952 90
Balance unexpended of the income for 1877		4,054 72
Balance at the beginning of the year 1877		21,029 18
Cash balance, January 6, 1878		$25,083 90

HAMILTON BEQUEST.

Received from James Hamilton, February 24, 1874, and deposited in the United States Treasury			$1,000 00
Interest received from February 24, 1874 to December 31, 1876			183 85
Interest received from January 1 to June 30, 1877	$30 00		
Premium, $5\frac{5}{16}$	1 59		
	31 59		
Less commission	04		
		$31 55	
Interest received from July 1 to December 31, 1877	30 00		
Premium, $2\frac{11}{16}$	81		
	30 81		
Less commission	04		
		30 77	
			62 32
Total income received to December 31, 1877			246 17
Appropriated in 1876, for exploration of cave near Carlisle, Pa			150 00
Balance on hand January 1, 1878			96 17

Statement of expenditures in 1877, in detail.

BUILDING.

Repairs and improvements	$2,325 46	
Fire-proofing apartments for collections	1,343 34	
Furniture and fixtures	361 86	
		$4,030 66

GENERAL EXPENSES.

Meetings of the board	$197 50	
Lighting	238 09	
Heating	1,029 10	
Postage	162 31	
Stationery	286 16	
Incidentals, ice, insurance, &c	560 60	
Salaries	11,780 00	
Labor and extra clerk hire	1,382 11	
Books and periodicals	416 77	
		$16,052 64

PUBLICATIONS, RESEARCHES.

Smithsonian Contributions	$6,412 46	
Miscellaneous collections	2,205 81	
Annual report	994 09	
Meteorology and researches	985 43	
Apparatus	1,406 14	
Laboratory	63 38	
Explorations	879 50	
		12,946 81
Literary and scientific international exchanges		9,790 73
Gallery of art		1,710 83
Museum		421 23
Total		$44,952 90

REPAYMENTS.

The Institution, as heretofore, has made temporary advances during the year for the payment of freight on government collections, &c., the repayment of which, together with the amount received from sales of publications of the Institution, have been deducted from the several items of expenditure for the year, as follows, viz:

From exchanges, repayments for freight	$459 65
From postage, repayments	7 42
From publications, sales	484 30
From National Museum, repayments	427 34
From electrotypes of wood-cuts	87 50
Total	$1,446 21

ESTIMATES.

The following are the estimates of receipts and appropriations for the year 1878:

Estimated receipts.

Interest on the permanent fund receivable July 1, 1878, and January 1, 1879, in gold	$39,000 00
Interest on the Hamilton fund for the year 1878, in gold	60 00
Probable premium on gold, 2 per cent	781 20
Sale of Virginia coupons due January 1, 1878, and July 1, 1878	2,500 00
	$42,341 20

Provisional appropriations.

For building	$2,000 00
For general expenses	15,000 00
For publications and researches	15,000 00
For exchanges	9,000 00
For books and apparatus	1,000 00
For contingencies	341 20
	$42,341 20

NATIONAL MUSEUM.

The government collections of specimens of natural history, ethnology geology, &c., continue in charge of the Smithsonian Institution, and Congress has made the necessary appropriations for their care and preservation, and for defraying the expense of packing, moving, and storing the articles received at the close of the International Exhibition in Philadelphia. The advances made by the Institution in previous years for the construction of a laboratory of natural history, required for the preparation of new specimens for the Centennial, have also been refunded.

The following is a statement of the National Museum appropriations for 1877 and 1878, and the balances at the beginning of the year 1878:

The appropriation by Congress for the care and preservation of the collections for the fiscal year ending June 30, 1877, was $10,000. Of this amount $5,090.86 were expended up to December 31, 1876, and the balance of $4,909.14 has been expended during the six months ending June 30, 1877.

For repairing and fitting up the "Armory Building," and storing the specimens received from the International Exhibition, an appropriation was made by Congress of $4,500, of which $3,916.23 were expended in the six months ending December 31, 1876, and the balance of $583.77 has been expended during the first six months of 1877.

APPROPRIATIONS BY CONGRESS FOR NATIONAL MUSEUM IN 1877.

Preservation of collections, Smithsonian Institution, 1878.

"For preservation and care of the collections of the National Museum"	$18,000 00
"For expenses of making up into sets for distribution to colleges and academies, the duplicate ores, minerals, and objects of natural history now belonging to the United States, or in the collections of the International Exposition presented to it by foreign governments." Act March 3, 1877. (Digest of Appropriations, 1878, page 86.)	5,000 00
	$23,000 00

Preservation of collections, Smithsonian Institution, Armory Building, 1878.

"For fitting up the Armory Building for storage of articles belonging to the United States, including those transferred from the International Exhibition, and expense of watching the same"	$2,500 00

National Museum, Smithsonian Institution.

"For the National Museum in charge of the Smithsonian Institution, for restoring to their proper place in the National Museum cases removed to the International Exhibition, and rearranging the collections, and for expenses and preservation of the collections, and for receiving, packing, and transporting the objects presented to the United States at the Centennial by State and foreign governments, and for properly storing and preserving them until a proper disposition can be made of the same." Act March 3, 1877. (Digest of Appropriations, 1878, page 86.)	$25,000 00

The total receipts of the Museum for the year 1877 have therefore been—

Preservation account, for fiscal year ending June 30, 1877 (balance)		$4,909 14
Armory account, for fiscal year ending June 30, 1877 (balance)		583 77
Preservation account, for fiscal year ending June 30, 1878.		23,000 00
Armory account, for fiscal year ending June 30, 1878		2,500 00
National Museum (return of Centennial collections, &c.), for fiscal year ending June 30, 1878		25,000 00
		$55,992 91
Expended during six months ending June 30, 1877:		
Preservation	$4,909 14	
Armory	583 77	
	$5,492 91	
Expended during six months ending December 31, 1877:		
"Preservation"	$11,676 79	
"Armory"	1,011 75	
"National Museum"	22,959 10	
	$41,140 55	
Balance January 8, 1878, to the credit of the Museum, to defray expenses of the collections for the six months ending June 30, 1878		$14,852 36

All the payments on account of the National Museum have been made directly by the disbursing-officer of the Department of the Interior, on the presentation of vouchers approved by the Secretary of the Smithsonian Institution.

SUMMARY.

The Executive Committee have examined six hundred and seventy-six vouchers for payments made from the Smithson income during the year 1877, and six hundred and eight vouchers for payments made from appropriations by Congress for the National Museum, making a total of 1,284 vouchers. All of these vouchers have the approval of the Secretary of the Institution and the certificate that the materials and services charged were applied to the purposes of the Institution.

The Committee have also examined the account-books of the National Museum, and find the balance, as before stated, of $14,852.36 to correspond with the certificates of the disbursing-officer of the Department of the Interior.

The quarterly accounts-current, bank-book, check-book, and journal have all been examined and found to be correct, and to show a balance to the credit of the Institution on the 6th of January, 1878, in charge of the Treasurer of the United States of $25,083.90, to be appropriated to the current operations of the Institution.

Respectfully submitted.

PETER PARKER,
JOHN MACLEAN,
GEO. BANCROFT,
Executive Committee of the Smithsonian Institution.

WASHINGTON, *January* 22, 1878.

JOURNAL OF PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

WASHINGTON, D. C., *January* 16, 1878.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution fixing the time of the beginning of the annual session on the third Wednesday of January in each year, the Board met this day, but a quorum not being present it adjourned to meet on Wednesday, January 23, at 7 o'clock p. m.

WASHINGTON, D. C., *January* 23, 1878.

A meeting of the Board of Regents of the Smithsonian Institution was held this day at 7 o'clock p. m., in the office of the Secretary.

Present, Chief-Justice Waite, Chancellor of the Institution; Hon. William A. Wheeler, Vice-President of the United States; Hon. R. E. Withers, Hon. Hiester Clymer, Hon. James A. Garfield, Rev. Dr. John Maclean, Prof. Asa Gray, Prof. Henry Coppée, Hon. Peter Parker, and the Secretary.

The minutes of the last meeting were read and approved.

Excuses for non-attendance were received from Messrs Hamlin, Sargent, Bancroft, and Stephens.

The Secretary stated that on the 1st of November, 1877, the Vice-President appointed Hon. R. E. Withers, of Virginia, as a member of the Board of Regents, in place of Hon. J. W. Stevenson, of Kentucky, whose term of service as Senator had expired. He also stated that the Speaker of the House of Representatives, on the 14th January, 1878, had appointed the following Regents: Hon. Hiester Clymer, of Pennsylania; Hon. Alexander H. Stephens, of Georgia; Hon. James A. Garfield, of Ohio. He also laid before the Board a letter from Prof. James D. Dana, resigning his membership in the Board, on account of continued ill health, and stated that a joint resolution had just passed both houses of Congress electing President Noah Porter, of Yale College, Connecticut, to fill the vacancy.

Professor Henry presented a general exhibit of the condition of the Smithson fund and a detailed statement of the receipts and expenditures for the year 1877. He stated that to save time these statements and all the accounts of the Institution had been referred by him to the Executive Committee.

The subject of the Virginia bonds held by the Institution and the propriety of disposing of them was considered, the Secretary having

called attention to the fact that their present value was about $7,000 less than at the last meeting of the Board.

Mr. Withers was of the opinion that the temporary depression was due to fears of improper legislation by the State, and he could not predict what course would be pursued, but he believed it injudicious for the Institution to part with these funds at present.

The Chancellor and the other Regents concurred in this opinion.

Dr. Parker, from the Executive Committee, presented the following report relative to the portrait of the Secretary, ordered by the Board at its last annual session:

REPORT.

The Executive Committee, which were authorized and requested to have a life-size portrait of the Secretary of the Institution painted by some competent artist, report that after a full inquiry for the best artist, the chairman of the committee visiting New York solely for the purpose, consulting men acquainted with, and judges of, the artists of the city, and visiting the studios of some of the most distinguished portrait-painters and examining their works, their choice was between Daniel Huntington and Thomas LeClear, esqs.

Mr. Huntington, who had painted Professor Henry when a younger man, would have been happy to paint him again in the maturity of his years, but his health was delicate and he was averse to leaving home. Mr. LeClear could come to Washington and paint the portrait at once. The prices were essentially the same with both artists.

Mr. LeClear was decided upon, and he agreed "to paint a three-quarter length life-size, the canvas to be three feet by two feet nine inches, head and two hands, for $1,500, the same to be painted in the best style possible to him."

Mr. Huntington, on learning the decision of the Executive Committee, wrote: "I congratulate you on your choice of my esteemed friend, Mr. Thomas LeClear, to paint the portrait, which will insure you a work of rare artistic merit."

The committee have now the pleasure of presenting the Board of Regents the portrait of Professor Henry, the result of their endeavor to discharge the delicate duty devolved upon them.

PETER PARKER,
GEO. BANCROFT,
JOHN MACLEAN,
Executive Committee.

JANUARY 22, 1878.

On motion of Mr. Withers, the report of the committee was received and ordered to lie upon the table for the present.

Dr. Parker presented the annual report of the Executive Committee, signed by himself, Dr. Maclean, and Mr. Bancroft, relative to the receipts, expenditures, estimates, &c.

On motion of Professor Coppée, the report was adopted.

The Secretary stated that the "Memorial of the Board of Regents," relative to the new building for the National Museum, had been presented to Congress, and that a bill in accordance with it had passed the Senate, without objection, but it had been presented so late in the session that favorable action could not be obtained in the House of Representatives. A renewed effort would be made this session to accomplish the desired object. Several of the Regents expressed the opinion that the bill would be passed at an early day.

The Secretary presented to the Board a miniature likeness of James Smithson, founder of the Institution, and also one of Col. Henry Dickinson, his half brother, which had been purchased from Mons. de la Batut, of Belz, France, a half brother of the nephew of Smithson, who parted with them on account of pecuniary need and his desire that the Institution should possess them. Mr. de la Batut had also presented to the Institution a number of notes addressed to Smithson by Oersted, Arago, Biot, Tennant, Klaproth, and other distinguished scientific men of his time, showing his intimate association with them; also a draught, in Smithson's handwriting, of his will, differing in one very slight particular from the will as presented to the United States by the English Court.

Professor Henry gave an account of what had been received of the personal effects of Smithson, and stated that nearly all these had been destroyed in the fire at the Institution in 1865. He advised the republication, in a suitable form, of all the scientific papers of Smithson.

On motion of Dr. Maclean it was—

Resolved, That the Secretary be requested to have a memoir of James Smithson prepared and published, to include all his scientific papers now accessible.

On motion of Dr. Coppée it was—

Resolved, That the Secretary prepare and publish a history of the origin and progress of the Institution.

On motion of Dr. Coppée the Board adjourned to meet on Saturday, 26th instant, at 7 o'clock p. m.

JANUARY 26, 1878.

A meeting of the Board of Regents was held this day at 7 p. m., in the office of the Secretary.

Present, Chief-Justice Waite, Chancellor; Hon. R. E. Withers, Hon. James A. Garfield, Hon. George Bancroft, Hon Peter Parker, Dr. Asa Gray, Dr. Henry Coppée, and Professor Henry, Secretary.

Excuses for non-attendance were received from Messrs. Wheeler, Hamlin, Sargent, Stephens, Clymer, Maclean, and Porter.

The minutes of the last meeting were read and approved.

Professor Henry presented his annual report of the operations of the Institution for the year 1877, which was read in full.

On motion of Hon. James A. Garfield the report was accepted, and the Secretary directed to transmit it to Congress.

The report of the Executive Committee, relative to the portrait of the Secretary, laid over at last meeting, was considered.

On motion of Dr. Gray it was—

Resolved, That the Regents accept from the Executive Committee the portrait of the Secretary, procured in fulfillment of the resolution of the Board of February 5, 1877, and present their thanks to the committee for the satisfactory manner in which this duty has been accomplished.

The Board then adjourned to meet at the call of the Secretary.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1877.

The object of this appendix is to illustrate the operations of the Institution by reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the observers and other persons interested in the promotion of knowledge.

COLOR-BLINDNESS IN ITS RELATION TO ACCIDENTS BY RAIL AND SEA.

By F. Holmgren,
Professor of Physiology at the University of Upsal.
[Translated for the Smithsonian Institution by M. L. Duncan.]*

INTRODUCTION.

In several preceding memoirs I have treated the subject of color-blindness from the theoretical side of this singular phenomenon. But it has, likewise, a practical side of vast importance; for not only does this defect of vision every day give rise to inconveniences in the various departments of the sciences, arts, and industries, but it is also the cause of most disastrous accidents by rail and by sea. Public attention has been attracted to this side of the question by scientific works or by accidents, and to judge from certain facts reported in books and newspapers, there now seems to prevail a more general conviction of the necessity of making the sense of color amongst seamen and railway employés an object of official scrutiny and control in order to guard against this hidden danger, to which too little attention has been given. Our times are probably ripe for such a reform, and there is only wanting, it seems, for its immediate and general adoption, a practical method, a well-arranged plan, and initiatory energy. It is to supply these deficiencies that we have undertaken and published these pages.

To Sweden belongs the honor of having taken the initiative in this reform, and in such a manner as to exercise a full control over the sense of color on all our railways. This reform was promptly matured, and introduced in a not less rapid, sure, and systematic manner, which undoubtedly proves the advantages of the method, plan, and principles which were followed.

A knowledge of the method of investigation and of the principles relating to it has been so far disseminated merely by oral exposition and application before the physicians and railway employés in the Amphitheatre of Physiology of Upsal, during the latter part of the year 1876. Consequently, what is remarkable with regard to the subject is that the entire reform was established in Sweden before any rules or principles were printed. One of the most important causes of this fact is found in the conviction felt from the first of the advantages of speech over writing in such matters. The other reason is that our results were obtained with unexpected rapidity, and that the time devoted to it pre-

* This article has been necessarily somewhat abridged from the French translation: De la Cécité des Couleurs, dans ses rapports avec les Chemins-de-fer et la Marine, par F. Holmgren. Traduit du suédors avec l'autorisation de l'auteur. Stockholm. 8 vo. pp. 144. [1877.]

vented us from publishing this work before the reform was introduced. If this fact should render the publication of these labors less indispensable for the time being, we must not forget the importance and necessity of directions which will serve in the future for our own railways, as well as for the introduction of a similar reform elsewhere.

The importance of uniformity in the method of examination, in the classification, and in the principles relating to the disposal of the *personnel*, cannot be too highly estimated, for this is of consequence, not only to science, and especially to statistics, but also to a purely practical end. This fact becomes the more forcible when connected with the investigation of the sense of color among seamen; for every reform of this kind within the province of navigation naturally assumes an international character. Our classification as well as our method of examining the color-blind is founded upon the Young-Helmholtz theory, and we cannot refrain from enumerating here the principal elements. This theory is assuredly not the only one, nor even the last that has been given to the public and gained partisans; but it is, in our opinion, the best for the end in view, and it will be seen that it essentially responds, as far as regards practical interest, to all that we have a right to require of a theory. We have no intention of attempting to establish its correctness. We make use of it for a definite purpose, under the conviction that it is a needful basis for the systematic and accurate solution of some of the practical questions under consideration.

In brief, the object of this work is to give a practical and clear idea of the nature of color-blindness, of its importance to marine and railway service, and, finally, a concise summary of the principles to be followed and the measures to be taken in order to secure immunity from its peculiar dangers. The reason why we confine ourselves almost exclusively to railways here is that the reform in view has already been introduced into this department, and a valuable experience acquired. And it is clear that these results may equally well be applied to navigation, at least in all essentials.

Color-blindness in many other departments of practical life also leads to serious inconveniences, and as it is desirable that an examination of the chromatic sense be undertaken on a large scale in schools, as a guide in the choice of professions, we hope this memoir may serve in a measure to this end. We should, moreover, be very happy to have the opportunity (so rarely accorded to physiology) of being useful to humanity, without the intervention of practical medicine.

I.—HISTORICAL SKETCH.

Color-blindness has been known for a long time, and, therefore, has its history. The first cases known to the public are mentioned in a letter from Joseph Huddart* to Joseph Priestley, dated January 15, 1777,

* An Account of persons who could not distinguish colors. By Mr. Joseph Huddart, in a letter to the Rev. Joseph Priestley, L.L.D., F.R.S. Philosophical Transactions of the Royal Society of London. Vol. lxvii. For the year 1777, part i, p. 260.

just one hundred years ago. The cases in point were those of a shoemaker, named Harris, of Mary-port, in Cumberland, and his brother, master of a merchant-vessel, belonging to the same port. Although the description is very brief, several features, which at a later date characterized complete color-blindness, are recognized, and especially in the latter case the type of blindness known at present under the name of *red-blindness.*

The first case of color-blindness accurately described, known to us, is that of John Dalton, the celebrated English chemist and physicist. Unable to distinguish red, he studied this defect of nature in himself, and published in 1794 a detailed and accurate description of it.* It is after him that color-blindness received the name of *Daltonism*, an appellation which appears to have been employed for the first time by Pierre Prévost, at Geneva, in 1827, and was, therefore, in use during the life of Dalton, who did not die until 1844. It is not known whether Dalton was aware of this appellation, but, however that may be, he probably would not have objected to this use of his name, for according to George Wilson he was more amused than annoyed by his defect, he himself enjoying the amusement he afforded others by his mistakes in colors. His countrymen have, however, warmly protested against this manner of immortalizing the memory of Dalton by perpetuating a congenital defect, especially as his scientific merits are sufficient to render his name imperishable. But notwithstanding these protestations, and the universal use in England of the name of *color-blindness*, which was first introduced by Sir David Brewster, and is now in general use in Germany (*farbeblindheit*), the terms *Daltonisme* and *Daltonien* are still in common use in France.

Dalton also cites a number of instances of color-blindness, similar to his own, and later a host of others are mentioned by different authors; but, on the whole, these are isolated cases accidentally encountered, and considered as curiosities, and their most striking features described and discussed, but with no knowledge of how to reduce them to fixed laws. For this purpose, three things were especially wanting: a practical method of investigation, a large material for the purpose, and a satisfactory theory for direction in the employment of this material.

Seebeck was the first to interest himself especially in systematically collecting a number of cases relatively very large, and in comparing them with each other. In 1837 he made a strict examination of the students of one class in a school in Berlin, and gave a detailed account of twelve cases of complete color-blindness examined by himself, and of one mentioned by his father, as well as a few other instances more or less color-blind, which form the transition between complete color-blindness and the normal chromatic sense. Seebeck understood the uncer-

* Extraordinary facts relating to the vision of colors: with observations by Mr. John Dalton, read October 31st, 1794. Memoirs of the Literary and Philosophical Society of Manchester. Vol. v, part i (1798), p. 28.

tainty and inadmissibility of attempting to discover the nature of this blindness by simply interrogating the color-blind as to the names of the colored objects; he was careful to note what mistakes they made in comparing the colors, or, in other words, he ascertained between what colors, different to the normal eye, they found resemblances. Following up this principle, he proceeded methodically to examine individuals; he invited them to arrange, in the order of their resemblances to each other, a number of colored objects, which in the beginning were in confusion. He used principally paper, about three hundred pieces of different colors, not, however, rejecting other materials, especially pieces of colored glass. He objected to silk on account of its brilliancy, but recommended wool, although he does not appear himself to have preferred to use it. It is not clear from Seebeck's writings whether, after each examination, he preserved the order in which these pieces of paper were arranged by the color-blind; but it is certain he compared the manner of arranging them in different cases, and drew his own conclusions. By this comparison, Seebeck succeeded in pointing out two classes of specifically distinct color-blindness. Of the thirteen cases he examined, eight belonged to the first and five to the second class. Moreover, he shows that in the two classes there is a great variety of degrees of color-blindness, and seeks further to prove the probable existence in the two classes of a gradual transition to the normal sense of color.

But Seebeck and his contemporaries, like their predecessors, could not discover a satisfactory explanation of the defect in question, or practically see its relation to the normal sense of color. This is easily explained by the fact that at this time there was not the least plausible system of a physiological doctrine of colors. Indeed, as early as the beginning of our century, a useful and satisfactory theory had been devised by Thomas Young, but it had been neglected or forgotten, as were many of the other ideas of this extraordinary man, who was far in advance of his age, and consequently not understood. The theory of the three primitive colors, or fundamental perceptions, of Young, was rescued from oblivion by Helmholtz about the year 1850, and also later, but independently, by Maxwell. This theory has undoubtedly already exerted a very happy influence over the physiological doctrine of colors in general, as well as over that of the anomaly in chromatic perception. In designating this theory by the names of both scientists, we thereby simply render justice to the merit which accrues to Helmholtz for having revived and applied it. Owing to this theory, the question of the nature of color-blindness has been of late the object of strong and growing interest. The number of cases, and also of treatises on the subject, have increased very considerably, and the study, undertaken by physiologists as well as by ophthalmological practitioners, has not been confined to congenital color-blindness and its different forms, but has also extended with much earnestness over pathological diagnostics. It is only about ten years since that a new theory, that of four cardinal colors, succeeded in making

many partisans. But when will it be in a condition to meet the exigencies of the physiological doctrine of colors in a more satisfactory manner than the Young-Helmholtz theory? This is yet unknown. With regard to the defect now occupying our attention, it seems very doubtful, to judge by the trials that have been made, whether this theory would better meet practical necessities than that of the three cardinal colors. And it is precisely these practical requirements that have led us to mention the theory here.

Up to the present time, the theoretical problem of color-blindness has undoubtedly been the object of more serious attention, and has been richer in results than the practical. Now, as the latter is nevertheless of singular importance, and the difficulties to be encountered to solve it in a satisfactory manner seem, in many respects, of only secondary importance, it is not easy, in reality, at the first approach, to find a suitable explanation. It will not, therefore, be uninteresting, we believe, to cast a rapid glance over this side of the question from a historical point of view, which will, in the first place, bring out the fact of which we speak, and perhaps also contribute to bring to light the point at which it is necessary to look for the cause of this state of things. The first writer who seriously occupied himself with the investigation of color-blindness in the various departments of practical life, and especially drew attention to the possible accidents occasioned by the employment of color-blind individuals on railways and at sea, and generally in all operations where colored signals are used, was George Wilson, professor of technology at the University of Edinburgh.* Wilson's researches were purely practical in aim and end. The mistakes made by the students of his laboratory in judging the colors of chemical precipitates led him to reflect upon this subject, after reading the memoir in which Dalton describes his own anomaly. For a long time, he tells us he scarcely dared suspect any of his pupils of having so rare an infirmity, but, like many after him, he took courage, proceeded to make an examination, and found that not only were his suspicions perfectly correct, but that color-blindness was far from being so uncommon as usually supposed.

He dilates at length, in his memoir, on the peculiar characteristics of seventeen color-blind individuals; eight were examined by himself, and the others described by different observers, or the color-blind themselves. These cases were distributed as follows: fourteen men and three women; sixteen cases were congenital, and one proceeded from a cerebral affection caused by a fall from a horse. It must be remembered that this last case had not been examined before the accident; a circumstance rendering the verification of the pathological origin of color-blindness difficult, but the description seems to authorize

* Researches on color-blindness, with a supplement on the danger attending the present system of railway and marine colored signals. By George Wilson. Edinburgh, 1855.

the conclusion that the case was correctly judged. Besides these cases described in detail, and illustrated by a number of interesting anecdotes, Wilson cites a great many others analogous, but only accidentally encountered by our author, or mentioned to him by other persons, for which he was indebted to the interest the question had excited in England by his own initiatory steps. Wilson's data are not merely limited to this kind of investigation. He also mentions the systematic researches, (analogous in some measure to those of Seebeck,) which he undertook in order to discover color-blind individuals, and by that means form some idea of the frequency of color-blindness amongst the population. It is to him, in fact, we owe the first efforts to establish regular statistics on this subject, as it would be difficult to receive as such the cases collected by Dalton. To attain this end, Wilson examined at the same time a large number of individuals belonging to the same class, such as soldiers, students, police-agents, veterinary students, etc., and discovered in this way 65 color-blind out of 1,154 persons examined; that is, 5.6 per cent., or one color-blind out of every 17.7 persons. If desired that statistics of this nature should render the service expected, it is plain that there must be great strictness in the use of the methods of examination, and especially in any case where a doubt of color-blindness exists. Here, as in the classification of color-blindness in general, theory exercises great influence. In this respect, it is very important that uniformity should prevail, or at least that, at the time of the employment of the different theories and methods, the limits should be well defined between color-blindness on one hand, and, on the other, between the different kinds of anomalies, and finally that the process should be so selected for examination and classification that from any practical point of view an accurate judgment could be formed of the result, and a classification made of the different cases under any system whatsoever. It is only by fulfilling these conditions that these statistical data can be useful; and that they may have a real value, it is the more necessary that the method should be so sure that no color-blind individual could escape the experimenter.

It is impossible to say that Wilson's statistics fulfill these requirements. Wilson was not ignorant of Young's theory as restored by Helmholtz and Maxwell. But this theory had not as yet begun to excercise a general influence over the ideas of the nature of the anomalous perception of colors, the methods employed in discovering it, and the manner of classifying the different forms. Wilson's method and classification therefore are deficient. His method consists in presenting to the individuals to be examined pieces of colored paper, one after the other, or a diagram in an illustrated work, and asking the names of the colors. Those only who evince some hesitation in distinguishing red, green, and brown are required to submit to Seebeck's proof, that is to say, classifying according to their analogy, but without indicating by name the pieces of colored paper, glass, or wool. From this it can be

quite positively concluded that this method is not altogether safe. Wilson acknowledges as possible that some of the color-blind might pass unperceived, especially when, to save time, the examination is made more hastily than the method allows.

The classification is not better regulated; in fact, it distributes the color-blind into three classes: 1st, those who confound red with green; 2d, those who confound brown with green; and, 3d, those who confound blue with green. This distribution is not founded upon any theory, nor is it either the exact expression of well-defined kinds. Wilson himself agrees that those who make the mistakes characterizing the first class do not fail to make those of the second also. The second group might therefore be correctly regarded as the same kind as the first, of an inferior degree. With regard to the third class, it is more than doubtful whether the greater number of the cases which it includes can be classed under the head of color-blindness. It also seems that Wilson hesitated with regard to this, since he has excluded this group from one of his tables. This class contributes the most also in rendering the proportion of color-blindness as great as Wilson found it. From these statements, the statistics given by this author cannot be regarded as very useful. Besides, the number of cases examined is too limited, especially as the particular figures forming the sum-total differ considerably among themselves. There is, however, another reason rendering Wilson's work of great importance, and worthy of being especially mentioned here. Wilson's constant aim, in fact, was to direct attention to color-blindness in its connection with practical life, and that in a very extended sense. He shows that an individual whose anomaly from infancy has been established should avoid selecting a profession in which his defective sense of color might occasion difficulties and annoyances to himself as well as to others. According to Wilson, the color-blind should never become painters, dyers, weavers, tailors, chemists, botanists, geologists, physicians, etc. Amongst the occupations in which the color-blind risk being the cause of embarrassments and annoyances to themselves as well as to others, and of real and serious accidents, Wilson especially mentions those of the sailor and railway employé, because the color-blind, who have a peculiar tendency to confound the very colors employed as signals at sea and on railways, may in this way occasion even death itself.

Wilson does not confine himself to pointing out these dangers to their full extent, but proposes preventive measures. For this purpose, he suggests very sensibly the only two measures that could be taken: to preserve the colored signals in actual use,—red (= danger), green (= attention), and white (the ordinary light of lanterns, that is yellow = clear track), and in this case eliminate all the color-blind; or else retain all, and change the signals. Wilson decides in favor of the latter alternative, which he considers preferable. He says that the managers of railways have been very unfortunate in their choice of colors, selecting precisely those, red and green, the color-blind confound the most.

This opinion does not extend to the signals used during the day. But Wilson fails, and very naturally, when he proposes other colors preferable, according to his judgment, for night-signals; for example, a blue light, excellent in all other respects, cannot fail to be useless in consequence of the small amount of power it is capable of acquiring in an ordinary lantern. Wilson reaches the conclusion that colors should be discarded as principal signals; they should be employed, he says, only as auxiliary, and founds his system of signals on *form*, *motion*, and *number*. He enlarges to some extent upon this subject in a supplement to his memoir, into the details of which we cannot now enter.

The dangers which threaten travel by rail and sea, and the disasters resulting from mistakes of the color-blind with regard to colored signals, were clearly understood and distinctly expressed, and the measures to be taken to avoid them plainly proposed more than twenty years since. If, therefore, it is now asked, as would be natural, to what practical results all this has led, we might reasonably expect, especially when we recall the attention that Wilson awakened on the subject amongst his contemporaries, that an important reformation for assuring public safety would long since have been accomplished not only in England, but in every civilized country. A mere glance over the existing condition of things, however, reveals the fact that the answer is not satisfactory. The only practical result mentioned by Wilson in his work as a result of his writings, is the resolution of the Great Northern Railway Company that the entire *personnel* must in future prove themselves free from this defect of the chromatic sense before entering the service; and, as Wilson says, the public is indebted for this wise measure to one of the directors of the company, Mr. Graham Hutchison, whose attention was called to Wilson's works by Dr. Mackenzie, of Glasgow. We see by this that the numerous articles written by Wilson before publishing his views and experience in full had aroused public attention to an interesting phenomenon in the scientific world, but had not led to any practical application, except in the one case in which a physician had succeeded in personally interesting one of the directors of a railway company in the question. We know not how far other administrations have followed this example. It is very probable that this measure has not been adopted by a single company in Dalton's country, where color-blindness was discovered in the first place, and where it was studied with so much care that England was long regarded as the veritable land of this anomaly.

It would appear then that no considerable change has taken place in the matter since Wilson's time. With regard to the English navy, we still lack positive information.

With regard to France we are more fortunate. For a long term of years, Dr. A. Favre, of Lyons, was occupied with the practical side of this question, and made different investigations into the perception of colors, especially amongst the employés of the Paris-Lyon-Mediterranean Company, of which he was for a long time one of the consulting physi-

cians. He then proceeded to make an examination of soldiers, sailors, and students. The information we are about to give is principally derived from Dr. Favre's pamphlet, which he kindly sent us.

We will give a brief statement of his statistics, his method, and his idea of color-blindness, and then his propositions for practical measures.

In relation to the frequency of color-blindness amongst the *personnel* of railways, Dr. Favre tell us that out of 1,196 candidates examined by him from June, 1864, to December, 1872, thirteen were red-blind and one green-blind (1.17 per cent.); but out of 728 employés of the same line examined in 1872 and 1873, he found not less than 42 cases (5.76 per cent.) of color-blindness more or less pronounced, and that although 276 amongst them had previously submitted to an examination for the same defect. During a subsequent examination, from July, 1873, to October 1, 1875, he discovered, amongst 1,050 men from eighteen to thirty years of age, nearly all formerly soldiers, not less than 98 color-blind (9.33 per cent.). The increasing proportion of color-blindness at each series of inspection must be attributed to the modifications introduced into the method and diagnosis, owing to which a comparatively much larger number of cases has been classed under the head of color-blindness. This large proportion is easily explained by the method and manner of making the diagnosis. Dr. Favre's method, which he has developed from year to year, consists in this: he presents to the subjects to be examined wool of different colors corresponding to those of the spectrum, *red*, *yellow* (including *orange*), *green*, *blue* (including *indigo*), and *violet*, and demands the name of each of these colors. All who are at fault about them are pronounced color-blind. He regards also as such those who hesitate, and who, when the test is repeated several times, give to a color sometimes its own name and sometimes another. And yet, Dr. Favre thought it his duty to correct the result obtained at the last examination: from the 98 cases, he withdrew 29, who hesitated only in the designation of the colors, and 8, who, after repeated tests, corrected their preceding mistakes; the proportion falls by that from 9.33 to 5.8 per cent.

On two points, Dr. Favre has in his works announced new views, and whether they ought to be accepted or merely left to gain supporters, they are of a nature to produce consequences of great importance in the practical world. In fact, it has invited especial attention on one hand to *acquired* color-blindness, which is quite common, according to his pamphlet, on the Paris-Lyon-Mediterranean line, and results from various causes. On the other hand, he asserts that *congenital* color-blindness is not incurable, but can be remedied by means of assiduous and systematic exercise in colors.

The practical measures demanded by Dr. Favre, in accordance with his views and experience and that of his fellow-laborers, with regard to color-blindness, might be embodied in the following terms: an examination of the chromatic sense, obligatory upon all candidates for

railway employment, and upon those already in service; exclusion from active service of all who cannot distinguish red; especial examination of all employés afflicted with contusions or wounds on the head, or recovering from a serious illness; examination of drinkers and smokers; and, finally, a periodical examination of the entire *personnel* in active service; these last measures having reference to acquired color-blindness. These principles apply equally well to sailors. In behalf of his views on the curability of acquired color-blindness, in which he seems more and more interested, Dr. Favre earnestly urges the introduction of systematic exercise in colors in schools, in the army and navy, and on railways.

It is readily seen that these views, and the measures based upon them might have very considerable practical consequences; in fact, if they were proved by a decisive test, we would have the best and most radical means of preventing all the inconveniences and dangers that color-blindness might occasion. But, on the other hand, if the ideas of our honorable colleague prove to rest on but slight foundation, as is generally admitted so far, and as we ourselves believe, it is to be feared lest through an actual improvement in the chromatic sense, on which these measures depend, we might be led into error as to the ability that the color-blind often acquire by practice in designating the colors of common objects accurately by conjecture or the help of other characteristics, and, lulled into a false security, neglect the measures that should and might be taken. We are far from asserting that Dr. Favre's opinion on this point may have already exercised such an influence, but we cannot refrain from mentioning a circumstance, which, at all events, would not contradict such a supposition. In fact, Dr. Favre tells us that in 1875 the Academy of Sciences and Letters at Lyons voted resolutions calling the attention of the ministers, and amongst others that of the navy, to Dr. Favre's publications, and especially his request that sailors should be educated and exercised in colors. We do not know whether this decision has been put into practice, but we have no reason to doubt it. But, on the other hand, we learn, from special information, that up to the present (January, 1877) no examination of the chromatic sense has been exacted of those desiring to enter the French navy. Nevertheless, Dr. Favre's labors and his practical efforts in the cause of color-blindness have awakened genuine attention in France and Belgium. He tells us himself, also, that the greater part of the precautionary measures in use on the Lyons railway from 1857 have been since introduced on other lines, and quite recently on the Belgian railways. Moreover, Dr. Favre's example has enlisted the interest of several physicians in this cause. One of the most distinguished, Dr. Féris, surgeon-general of the navy, has written a memoir on the importance of color-blindness to navigation. This memoir describes an examination, by the author, of 501 sailors, amongst whom he discovered 41 cases, more or less affected with this anomaly of the chromatic perception, that is to say, 8.18 per cent. This large proportion is explained by the fact that Dr. Féris finally employed

the same method and made the same diagnosis as Dr. Favre, and nearly the same classification, with slight modifications.

The foregoing seems to show that the question is now exciting attention in France, and this owing to the activity of a single individual. It is obvious, however, that although Dr. Favre may have succeeded in introducing measures insuring the communications against color-blindness amongst the employés of the line to which he was himself attached, or those of other lines, no reform has been *generally* recommended or introduced on the French railways, and that absolutely no measures have been taken in the navy. Besides, it is evident from certain passages in Dr. Favre's pamphlet and from his opinion of the curability of congenital color-blindness, that the principles applied, where a control has been introduced, have not been particularly rigorous. As to the elimination of the color-blind *personnel*, it might with certainty be concluded that no rigid rule has been followed; from the fact that those only are discharged from active service who "cannot or only partially can distinguish red, and are consequently dangerous," and the fact that of the forty-two color-blind subjects detected by Dr. Favre in one of his examinations, nine only were removed from active service.

In Germany, where an interest in color-blindness has been lately excited in many quarters, but little is presented in regard to the control of this defect on railways and in the navy. We can supply only a few data capable of throwing any light upon the state of the question there.

In an article on the works of Dr. Favre, Mr. Blaschko points out the importance of seriously making the sense of color amongst the *personnel* of railways an object of official scrutiny and control, according to Dr. Favre's plan.

Dr Stilling in 1875 gave us still further information in an account of a method proposed by him for discovering color-blindness by means of colored shadows. "Here also in Germany," says he, "several railway companies have directed their attention to this subject (color-blindness), and the time is probably not far distant when investigation amongst railway *personnel* and others will be undertaken *ex officio* and *en masse*." We do not know how or in what measure this prediction may be realized, but inasmuch as the late movement in Sweden was regarded by the German papers as a new and extraordinary phenomenon, and as, moreover, one of the most eminent physiologists of Germany writes us that no general measures have been adopted with regard to it in that country, we may conclude that no practical reformation on the subject has been generally introduced there.

We hear from Holland that measures with regard to this defect are now on the road to execution.

A rapid glance over the development and existing state of this question in Sweden cannot be void of interest. In what is called the Lagerlunda case or trial, instituted in consequence of a railway accident, of which Lagerlunda in Ostrogothia was the theater, November 15, 1875,

and which at the time intensely excited public attention, testimony was adduced which led me to suppose that color-blindness was one of the principal causes of the disaster. This impressed me with the idea that official scrutiny and control should be exercised over the sense of color amongst railway employés. Without knowing what had been done or written with reference to this in other countries, I considered it my duty to take the initiative. After convincing myself that the steps to be taken should consist, with the preservation of the existing system of signals, in eliminating from the railway service all employés afflicted with color-blindness, or at least those with certain kinds and degrees, I regarded it, first, of the highest importance, to have a practical method which should render the discovery of the color-blind rapid and certain, without incurring heavy expense or requiring extensive preparations, and in consequence to be able to examine easily a considerable number of individuals. Then it seemed to me essential to endeavor to interest the high functionaries at the head of the railways personally in the matter.

As regards the method, I had already found one purely theoretic, which, while in agreement with that of Young-Helmholtz, proved to be practical in the examination of the color-blind. But this method was only intended for discovering the types of partial color-blindness (complete, according to the theory), but not the form of blindness I had ascertained by the perimetrical examination of the colored visual field, and defined under the name of incomplete color-blindness. The method received accordingly a new practical aim, and it became necessary, in consequence, to render it more accurate, and especially to make a trial of it by an examination of the masses, so as to determine, by experiment, the practical value of the method, and form an idea of the amount of color-blindness in our country, of which no one had the slightest conception. The desired occasion presented itself in the month of June, 1876, and I am indebteded to the politeness of Major-General Von Knorring and Major Rudbeck for permission to examine 2,220 men belonging to a regiment of infantry, cantoned in Upland (standing army and militia), and to the dragoons of the guard (militia). The method proved to be capable, in its extraordinary simplicity, of perfectly answering the end in view with reference to rapidity and accuracy. The examination of each man required, on an average, one minute, sometimes more and often less; and with the improved form we had given the method, we also discovered, with accuracy, every individual incompletely color-blind. With regard to the knowledge acquired by this examination of color-blindness amongst the population of the province, we found that out of 2,220 men eleven could not distinguish red, seventeen green, one violet (?), and thirty-one were incompletely blind, according to the classification I had used. There were, then, in all, sixty color-blind, or 2.7 per cent.—The instances of a feeble sense of color are not included in this.

On the 14th of July, of the same year, I had an opportunity, before a congress of Scandinavian physicians assembled at Gothembourg, of giving an account of the method, of stating the results obtained by its use, and, besides, of expressing my views on the necessity of taking measures, on a large scale, for the detection of color-blindness, especially amongst railway employés. It resulted in the congress unanimously resolving that it was necessary to make investigations for the detection of color-blindness: 1st. Amongst employés of railways; 2d. Amongst pilots, light-house keepers, and sailors in general; and 3d. In schools. During the session of the congress I had an opportunity also of proving to the physicians the practical utility of the method by examining, in their presence, and with the permission of Colonel Carlsohn, 100 men of a regiment of artillery from Gothia, amongst whom we found four color-blind, namely, one red-blind, one green, and two incompletely blind. Besides, on the same occasion, we discovered amongst the medical members of the congress one green-blind, and amongst the audience one red-blind.

I was then advised to apply directly, in person, to the directors of railways. Thanks to the press, which had attentively followed up the debates of the Gothembourg congress, the question had reached the public. It naturally became an object of attention to railway officials, although received by a greater portion of them with a certain mistrust, seeing in it the result of a scientist's imagination or an overwrought solicitude, rather than a matter of practical application for the benefit of railways. "If color-blindness really exist," they said, "it cannot, at any rate, be amongst the employés, or it would undoubtedly have been remarked; especially must this be the case amongst the engineers and conductors, as they rise from inferior grades, and consequently have amply proved their ability to distinguish signals." It was therefore of extreme importance to endeavor to obtain at once positive assurance on this point. The opportunity soon presented itself. Mr. Jacobsson, superintendent-in-chief of the Upsala-Gefle line, invited me to accompany him in a tour of inspection to examine all the employés under his control. The trip was made in a special car; we left Upsal the 7th of September, and, to make our inspection, halted at every station and gate-keeper's and guard-house. In brief, we stopped at every place where an employé could be found. The investigation was concluded at Gefle, the 8th of September. The entire *personnel*, men and women, numbering 266 individuals, was examined. We discovered amongst these thirteen color-blind men, that is, 4.8 per cent.; six were completely green-blind, and seven incompletely blind. They were distributed as follows, with reference to their functions: one station-master, one engineer, two conductors, one foreman, two workmen (one a supernumerary), two overseers (one a supernumerary), two way-guards, one porter (messenger), and one journeyman engineer. Immediately after the examination, the general superintendent discharged all who were completely green-blind.

This first inspection was in many respects very interesting. It showed

that the method of inspection could be used and was expedient for railways. Moreover, it proved that there really were color-blind in almost every grade of service of a Swedish railway, and this without there having been the slightest suspicion of it, which confirmed my opinion of the utility and importance of enabling those employed on railways to convince themselves *de visu* of the nature of color-blindness and of its practical value to railways.

Relying upon the experience I had just acquired, I wrote, September 25, to the royal directors of the state railways, and called attention, amongst other matters, to the necessity of establishing a systematic control over the sense of colors amongst railway officials, and requested at the same time permission, in the presence of the directors, or a person designated for the purpose, to examine the officials attached to any railway whatsoever for the purpose of convincing the directors, in a practical manner, of the true nature and importance of the question. At this time the directors had already issued orders that as incapacity to distinguish primitive colors closed the avenue to railway employment, the physicians attached to the different lines must examine all applicants, and that heads of sections must afterward examine into whether any of their subordinates were incapable of distinguishing these colors, in the use of flags and ordinary signal-lights, in any way which seemed proper to them. On the other hand, however, debates and experiments on color-blind individuals, at the Physiological Institute of Upsal, had enabled me to succeed in interesting in the question several persons attached to railways, and amongst them all the directors of the Upsal-Gefle line.

In another letter to the royal directory, dated October 8, I invited the members to be present at one of these experiments, to be able to form a better judgment of the question. Two engineers of the railway presented themselves October 11, and on the 13th the chief director, Mr. Troilius, came in person. From this day success seemed assured. As early as October 16, the directors ordered that a physician from each district, and as many more as should desire, should assemble at my office at an appointed time, to acquaint themselves with the methods that I would explain to them relative to the examination of cases of color-blindness amongst the railway *personnel.* In consequence of this, at the appointed time, October 24, twenty-six physicians attached to railways assembled in the Amphitheater of Physiology at Upsal, and also thirty-two individuals employed on railways, amongst whom were the heads of nearly all the lines belonging to the private companies of the country.

November 9, the managers directed the physicians of the lines to proceed gradually, and according to my method, in the examination of all the men then employed on railways. Those of the physicians who did not understand this method, added the circular, should study it, either with me, or with one of the physicians who had been

present at my lectures on the subject; and finally the superintendents must send a report of the result of this examination, suggest measures to be taken, and in certain cases apply those that circumstances might require. In this way the reform was actually introduced on the railways of the state. The example was soon followed by the private companies (we do not know of a single exception), and although all the reports have not been returned (February, 1877), and consequently the result is not yet perfectly known, we might assert that the examination itself is finished everywhere, in an almost if not entirely thorough manner. Every case during the examination pronounced doubtful in the diagnosis, or where doubt existed about the measures to take with regard to it, has been reported to me. Sweden is consequently the first and only country, as we see, where the control in question has been generally adopted, and applied according to determined principles.

We have enlarged to some extent on the manner in which this matter has been successively accomplished in our country, not simply to give our experience on the subject, but rather that such details seem to us to elucidate the question occupying us. This will be clearly evident if we compare other countries with our own with regard to this. Let us recall the following facts: In England, color-blindness has been known for a century, and for more than twenty years a strict control over the sense of color amongst railway employés and sailors has been demanded. In France, a physician attached to a railway has been for a long time interested in color-blindness amongst its employés, and has been endeavoring for at least three years to introduce a general control on railways, in the navy, and in schools. Finally, in Germany, color-blindness has been for a long time a subject of scientific study, where the necessity of a control of the railway officials has been urged by a number of people of late years. Well, we have seen that in spite of all this, not one of these countries has yet decreed or introduced a general control on railways and in the navy. In Sweden, on the other hand, where color-blindness had scarcely been mentioned until the last few years, and where a proposition to examine railway officials was only publicly made July 14, 1876, and referred to directors of railways September 25, of the same year, this important reform may be already regarded (February, 1877) as actually and thoroughly established, in all essential details, on the entire system of railways throughout our country. To complete our data, it may be added that since November 12, 1876, the king has issued orders that, at the time of a general review of the fleet, every man should be examined with reference to color-blindness. This result is so truly remarkable that we cannot refrain from endeavoring to discover the probable explanation of the unexampled rapidity with which it has been reached in our country. The explanation does not seem to us difficult. In our opinion, it is chiefly owing to two circumstances: one is the method employed, which is not only accurate, as well as simple and rapid, but effects so palpable a result that the most skeptical observer

is struck by it; the other circumstance is the manner in which the knowledge of the method, as well as the principles for the introduction of an official control, has been spread throughout our country. This publicity was not reached in the usual way, through the medium of books, but by oral exposition, practical application, and *de visu*. Our idea is confirmed by the fact that this personal influence is recognized in the cases brought to our knowledge in England and France, where the scrutiny and control over the sense of color amongst the *personnel* of railways has been introduced, particularly on the Great Northern Railway of the first-named country, and the Paris-Lyons-Mediterranean line. But even without this support, our experience would sufficiently convince us that it is important, if not necessary, to explain the question orally and *de visu* to the physicians, and especially to railway employés. Speech, in such cases, has an undoubted advantage, and our experience of the last months of 1876, when the Amphitheater of Physiology at Upsal was often the resort of physicians, railway officials, and individuals afflicted with color-blindness, proves to us that this kind of communication, especially in such a case as that now before us, undoubtedly exerts a more powerful influence than the best written book.

The warm interest with which the question has been followed up by the journals is too important a circumstance to be forgotten. Not only has this kept the public on the alert, but the movement begun by us has been continued in other countries. Immediate effects were visible amongst our neighbors. In Finland, Dr. L. Krohn, who acquainted himself by correspondence with the method and principles used in Sweden, has already examined the railway officials of his country. A locomotive and ambulance were placed at his disposal for examining the *personnel* the whole length of the line. All was accomplished in twelve days. He discovered amongst twelve hundred individuals examined, sixty color-blind, that is, 5 per cent. They were distributed as follows: four red-blind; twenty-five green-blind; and thirty-one incompletely blind.

We have as yet heard of no results from our method in Denmark and Norway, but the question is there under serious examination, as the Physiological Institute of Upsal has been visited on different occasions by two Danish physicians, Dr. Slidelin and Dr. Fontenay, sent by the railway managers of Zeeland, and by Mr. Hagen, assistant at the Physiological Laboratory of Christiania, sent by the Medical Board of Norway at the suggestion of Professor Worm-Müller. I have thus had the pleasure of explaining to them the method of examination as well as the practical principles and rules I propose to communicate in this work.

II.—THE NATURE OF COLOR-BLINDNESS.

It is not my intention to treat this question in a thorough manner, but simply to mention what is essential to the practical end in view.

It has been known for a long time that every one does not possess

the power of distinguishing colors in the same manner, and that some exhibit a divergence of such a nature as to excite surprise and amusement. The confusion of green and red is very common. But, in many instances, the difficulty consists merely in discriminating between delicate shades, while the principal colors are easily distinguished. How shall we explain all this; how find the relation existing between the normal sense of colors and the abnormal; and where must the limit be drawn?

1.—THEORETICAL SKETCH.

Every one knows that a radiant body creates, throughout the ether which surrounds it, undulations which are propagated in every direction. When these undulations—whether they proceed directly in right lines from the radiant body, the sun for example, or whether they are reflected by some intervening body encountered in their course—come in contact with special organs of sense, they produce certain corresponding changes, which, in their turn, excite certain perceptions in our mind. If the undulations come in contact with our skin, we experience the sensation of heat; if they strike the retina, that of light. It is consequently our own brain that produces both light and heat, resulting from certain changes that take place in our organs of sense (the retina or the skin), although by these names we designate the external cause, when we say that the rays of light and heat proceed from the incandescent body. Nevertheless, to thoroughly understand this fact it is necessary on the one hand to distinguish between light and heat in an objective sense, which are virtually the same thing, that is to say, undulations of the ethereal medium: and, on the other hand, between light and heat in a subjective sense, which are sensations of an altogether different kind. We have, in the first place, here to consider our perceptions, and as their most immediate cause is found in a modification or activity of our own organs of sense, whatever be the external cause, it is clear that we must seek the explanation of all luminous phenomena in our special organism—the optic nerve; comprehending by that term the retina, the optic nerve, and those portions of the brain with which they communicate.

If all the undulations of the luminous ethereal medium were exactly of the same nature, or, on the contrary, if all the elements of our optic apparatus reacted in the same way on every kind of undulations of the ethereal medium, we could with difficulty imagine sensations of light of a different nature. Every specific activity of our apparatus of the optic nerve would produce a perception of light which would vary in degree, but not in quality. We could have no conception of, according to the cases, a light of different kinds, that is to say, of color. But, on the one hand, the science of physics teaches that the undulations of ether are of various kinds, differing in the rapidity, and consequently in the length of the waves; and, on the other hand, the subjective qualities of light, or our perceptions of color, fall within the range of our daily experience.

It belongs to theory to discover the law regulating these two factors. All the qualities of light must depend upon functional differences of the elements of the organ of the optic nerve. A necessary alternative is, either this organ has but one kind of elements, and then different kinds of undulations of the ether induce it to act under different forms, or else there are several kinds of elements or terminal organs in the retina or in the brain, which always act respectively in the same way, while differing from each other. This latter hypothesis accords better with all we know otherwise of the physiology of the nervous system, and is virtually but J. Müller's principle of the specific energies of the senses applied in detail to the sense of sight. It is also on this last hypothesis that the Young-Helmholtz theory is based.

The following is the principle upon which this theory explains the qualities of light or colors. When one kind of element alone is excited or set in motion, or when all are simultaneously excited, but one in a higher degree than the rest, our sensation takes hold of that element as the quality of the light, as the colored light or color, and particularly the cardinal or primitive color, which corresponds specifically to the excited element. If there are several kinds of elements, and only two of these are excited or more excited than the rest, we see the light colored, but of a color which constitutes the combination of the two colors corresponding to the excited elements. It is clear that the principle on which this reasoning is based gives room for the admission of as many different elements, and, consequently, primitive colors, as could be desired. At all events, it results from the principle that when all the kinds of elements, whether there be one or several, are excited simultaneously with the same force, there is no possibility of perceiving the quality of light. We then see but a light in general, in contradistinction to the absence of light or darkness; in other terms, we see a colorless light, or, as it is called, a *white light*, and incorrectly a *white color*. It follows therefore that when one element is principally excited while the rest are also excited, but in a less degree, the perception of the specific quality of the light is feeble in proportion to the degree of excitation of the other elements, since this effect of their excitation must be, in short, like a mixture of colorless light, or white relatively to the color in question.

Let us now see how the Young-Helmholtz theory applies the principle we have just explained. It recognizes three cardinal colors, *red*, *green*, and *violet*, and consequently three kinds of corresponding elements in the organ of the optic nerve; elements respectively perceiving red, green, and violet. When the perceptive element of red is excited alone, or in a greater degree, we experience the sensation of red, and so on. Different kinds of undulations of the ethereal medium excite, in different degrees, the different elements, but in such a way, however, that all excite in some measure each of these elements.

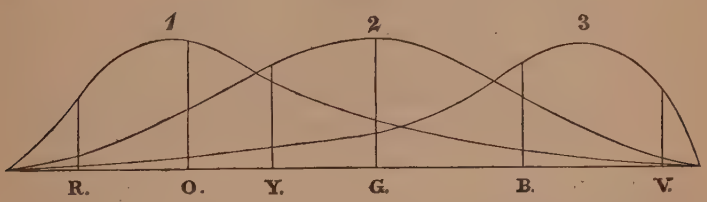
Without attempting, from a scientific point of view, to explain the dif-

ferent kinds of objective light in the length of the wave, in the practical course we are pursuing here it is much more convenient to designate them by the effect they exert on the normal sense of colors. With this explanation we will then proceed to speak of red, green, and violet light, and so on, meaning those ethereal waves which differ in length, in duration of undulations, in refrangibility, etc.

The easiest and most convenient means of describing the relations existing between the kinds of objective light and the excitability of the different elements, or, in other words, of the different kinds of subjective light, will be to construct a diagram in which the curves indicating the different kinds of light will be traced on an abscissa according to the order in which they are presented in the solar spectrum, and those which indicate the excitability of the respective elements, or rather the intensity of the sensation of colors, will be expressed by the ordinate. To save space, and more easily to comprehend the whole, we have drawn the curves of intensity of the different elements on the same abscissa, which consequently serves for each one of them.

Figure 1 represents this diagram, showing the normal sense of colors. The spectral colors are here found placed horizontally in the natural order, beginning with the red (R.), and finishing with the violet (V.); the three curves of excitability, namely, 1st, that of the organ perceiving red; 2d, that of the perceptive organ of green; and, 3d, that of the organ perceiving violet; these curves indicate the manner in which the different systems of waves of solar light act on each of the three elements sensible to light.

FIG. 1.



According to these curves, the homogeneous *red*, from the extremity of the spectrum to beyond the orange, affects the perceptive elements of red strongly, in a much less degree those of green, and still less those of violet. From this results the sensation of *red*, which is transferred more and more into orange in proportion to the increase of the excitation of the perceptive elements of green. Homogeneous *yellow* intensely excites, and almost in the same degree, the perceptive elements of red and green, while only feebly affecting the perceptive elements of violet. Hence, the sensation of yellow, which is a combination of red and green. *Green* light strongly excites the perceptive elements of green, and very feebly and almost equally the two other elements. Hence, the sensation of green. Homogeneous *blue* excites quite strongly and almost equally the

perceptive elements of green and violet, but feebly those of red. Hence, the sensation of blue, which is a combination of violet and green. *Violet* light powerfully affects the perceptive elements of violet and feebly the two others. Hence, the sensation of violet.

These curves enable us to explain easily the colors of the spectrum by the theory. We find in what proportion each one of the three fundamental perceptions enters into it by measuring the vertical distance from their place on the horizontal line (abscissa) to the corresponding points of each of the three curves. It is then seen that there is no color of the spectrum into which but one primitive color enters exclusively. The two others also furnish their contingent. No one is therefore perfectly "saturated." They are more or less spread with white, and green is the least sensibly "saturated," or more whitish. The curves also show us that yellow and blue are at the same time whitish colors, and the most intensely luminous in the whole spectrum. When we again add that a color "saturated" in almost the same degree as the other spectral colors, proceeds from the homogeneous combination of red and violet, that is to say, purple, and its whitish shade, pink, we shall have said all, theoretically, that we have to say in relation to the normal chromatic sense.

To explain the abnormal sense of colors by the theory of the normal, we can, in advance, conceive various possibilities. Let us suppose that one of the three fundamental perceptions is wanting, or that one of the primitive colors is absent; it is clear that the whole chromatic system will be upset. It is evident, therefore, that this system must be completely different, according to the absence of one or the other of the three primitive colors. It is virtually just in this way that it has been attempted to explain cases of a strongly marked defect in the chromatic sense, or genuine types of blindness to color, found in real life. The term *color-blindness* has been justified by this, as it indicates in each case a genuine blindness to one of the cardinal colors. In this way, therefore, we distinguish, according to the kind of element wanting, three classes of blindness:

1st. Red-blindness.

2d. Green-blindness.

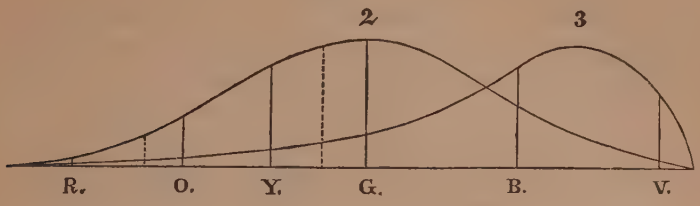
3d. Violet-blindness.

We shall see that the Young-Helmholtz theory, as we have explained it far from being contradicted, as has been recently claimed, by the phenomenon of color-blindness, finds in it, on the contrary, a support, and this theory most certainly furnishes the best guide for attaining the practical end in view for which we intend to use it. Let us, in the first instance, cast a rapid glance over the different kinds of typical and complete blindness to colors, as their features are presented by the theory. This sketch will be singularly facilitated by the use of the same kind of curves employed in illustrating the normal sense of colors.

1. According to the theory, blindness to *red* is due to the absence or paralysis of the organs perceiving red (fig. 2). Red-blindness has then

but two fundamental colors, which, adhering strictly to the theory, are *green* and *violet* (blue according to Maxwell).

FIG. 2.



The curves distinctly show what aspect the various kinds of lights of the spectrum must have for the chromatic sense such as the one we have in view. We will give a short list of them, according to Helmholtz, by designating here the different kinds of lights, as we did before, that is to say, by using terms borrowed from the impressions they produced on the normal chromatic sense; the comparison will not be without interest.

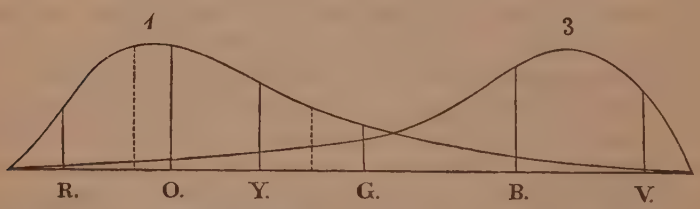
"Spectral red, which feebly excites the perceptive organs of green, and scarcely at all those of violet, must consequently appear to the red-blind a '*saturated' green of a feeble intensity*, more 'saturated' than normal green, into which a sensible portion of the other primitive colors enters. Feebly luminous red, which affects the perceptive organs of red in a normal eye sufficiently, does not, on the other hand, sufficiently excite the perceptive organs of green in the red-blind, and it, therefore, seems to them black. Spectral *yellow* seems to them a *green 'saturated' and intensely luminous*, and as it constitutes the precisely saturated and very intense shade of that color, it can be understood how the red-blind select the name of that color, and call all those tints that are properly speaking green, *yellow*. *Green* shows, as compared with the preceding colors, a more sensible addition of the other primitive colors; it then appears, consequently, like a more intense but whitish shade of the same color as yellow and red. The greatest intensity of light in the spectrum, according to Seebeck's observations, does not appear to the red-blind to be in the yellow region, as it does to the normal eye, but rather in that of the blue-green. In reality, if the excitation of the perceptive organs of green, as it was necessary to assume, is strongest for green, the maximum of the total excitation of the red-blind must be found slightly toward the blue side, because the excitation of the organ perceiving violet is then increased. The white of the red-blind is naturally a combination of their two primitive colors in a determinate proportion, a combination which appears blue-gray to the normal sight; this is why he regards as gray the spectral transitition colors from green to blue. Then the other color of the spectrum, which they call *blue*, preponderates, because indigo-blue, though somewhat whitish, according

to their chromatic sense is to them, owing to its intensity, a more evident representative of that color than violet."

This description of the manner in which the red-blind forms a conception of the different kinds of light of the spectrum is assuredly a conclusion logically deduced from the theory, but it accords so well, at the same time, with the experience acquired in examining the color-blind, that this might perfectly serve to support and corroborate the theory. We will simply add a point for our especially practical purpose, or rather emphasize one point of this theory. In fact, it is clear that a red and green light especially excite one and the same element in the red-blind. A ray red and green, or an object red and green, to the normal sense, must seem fundamentally to the red-blind to be the same color, and if, in especial cases, he knows how to discriminate, his judgment is simply guided by the intensity of the light. The intensity of light is much more feeble, as shown by fig. 2, in red than in green. If then a red-blind individual finds that a red and green tint are exactly alike, it is necessary that the green be to the normal eye much less intense than the red. This is distinctly shown by the vertical dotted lines between R. and O., and also between Y. and G., in fig. 2, and this is entirely confirmed by experience.

2. *Green-blindness* derives its origin, according to the theory, from the absence or paralysis of the perceptive elements of green. The green-blind has therefore but two fundamental colors, that is—still closely adhering to the theory—red and violet (blue according to Maxwell). The spectrum for green-blindness should be, according to the theory, constructed in the following manner:

Fig. 3.



The spectral *red*, which strongly excites the perceptive organs of red, and but very faintly those of violet, must therefore appear to the green-blind as an extremely "saturated" red, but of a light somewhat less intense than the normal red, which is comparatively more yellowish, as green forms a part of it. The spectral *orange* is again a very "saturated" red, but much more luminous. Yellow is undoubtedly a more intensely luminous red than the spectral red, but, on the other hand, more whitish, because a sensible portion of the other primitive color enters into it.

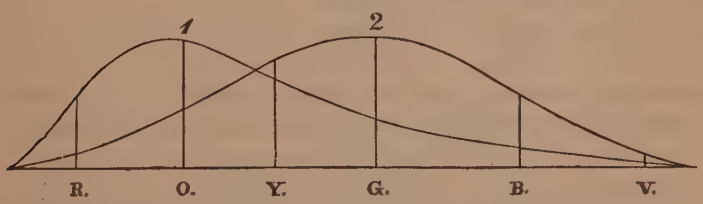
Green, with its shades inclining to yellow and blue, ought, correctly speaking, to be a "saturated" purple and with a mean intensity of

light, but it is the white (gray) of the green-blind, for it is composed of almost equal parts of the two primitive colors.

The *blue* is an intense violet, but a little less "saturated" than indigo, which is more strongly luminous and more "saturated." Violet is a little less intense, but more "saturated" than normal violet. The tints most luminous and at the same time most "saturated" which must constitute the types of the primitive colors of the green-blind are orange or its immediate neighbor in the spectrum, red, and indigo-blue. Now orange is a color which, in ordinary language, especially amongst the uncultivated and unpracticed, is indiscriminately called red and yellow; this fact explains why the green-blind denominate their first fundamental color sometimes "red" and sometimes "yellow." We will add to this description the same remark made about red-blindness. In green-blindness the same organ is also found affected by spectral red and green light. Red and green are then perceived by the green-blind in the same way, or, in other words, are to him in fact exactly the same color. In cases where he succeeds in distinguishing them, it is by the aid of the intensity of the light; but with regard to this intensity of light, it is the opposite of what occurs in the case of the red-blind. A green tint which to the green-blind must appear exactly like a red one, to a normal sense of color must be sensibly more luminous than red. This is shown by the dotted vertical lines between R. and O. and also between Y. and G. (fig. 3), and is confirmed in every respect by experience.

3. *Violet-blindness* (or blue according to Maxwell) is due, according to the theory, to the absence or paralysis of the elements perceiving *violet*. The two primitive colors of the violet-blind are then, according to theory, *red* and *green*. The spectrum of the violet-blind must in consequence be represented as follows:

FIG. 4.

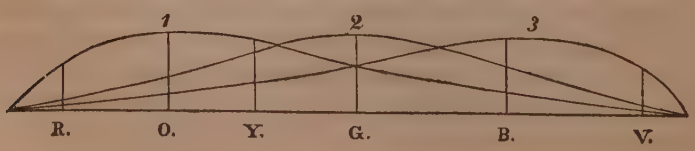


The *red* is a purer red color (not yellowish) than normal red, but still less "saturated"; the more it inclines toward orange the more strongly luminous it is, but is at the same time less "saturated," more whitish. The *yellow* is, as it were, a combination of almost equal proportions of the fundamental colors that form white. *Green* is a strongly luminous, but whitish green, which in tending toward the blue, becomes more and more "saturated," so that greenish blue must be the type of these hues. The *blue* is a green of moderate luminosity and strongly "saturated", and *violet* is green very feebly luminous, but also "saturated" in a much higher degree than the normal. A violet strongly luminous is sufficient

to induce this green, but a feeble violet, although very sensible to the normal eye, is black to the color-blind in question.

It is plain that the violet-blind, whose primitive colors are red and green, do not confuse these colors. This kind of blindness, from the experiments made so far, must be very rare. For our part we have not succeeded in discovering more than two cases agreeing quite exactly with the description given by the theory, while the first two kinds are comparatively very common. In order to be abnormal it is not necessary that a sense of color should completely fulfil the conditions indicated in the types we have just described. We might perfectly conceive a resultant, not of an absolute absence or of a complete paralysis of one kind of perceptive elements, but solely of a comparatively very low excitability, or, if preferred, of a much more limited number of one kind of elements, acting on the retina, as compared with the two other kinds. It is very easy to construct curves in conformity with this idea, and not less easy to arrange in this manner a continuous series of transitions and gradual forms between one kind of complete color-blindness on one side and the normal chromatic sense on the other. This kind of defective vision might be called *incomplete color-blindness*, to distinguish it from complete, as we have just characterized the three different kinds. Our experience has taught us that the intermediary forms agreeing with the data given above are met in large numbers in practice and of very different degrees. These are the forms we designated under the common appellation of *incomplete color-blindness*, but we can according to the theory still conceive other forms of a defective sense of color. There is one, amongst others, which has at command only one of the three kinds of elements. Such a sense of sight is not properly a chromatic sense. For it, there exists no specific difference in light, that is to say, no color. Every kind of light here acts as if on one element alone. This is why the single perception of differences of intensity of light (quantity), but not of differences of color (quality), is possible. This condition may then be designated under the name of *total color-blindness*. Several cases have been mentioned from time to time, but we have not succeeded in finding a single one, and it may well be questioned whether such a case has actually existed. We may also conceive that another form of a defective sense of color arises from the three kinds of elements being uniformly of moderate sensibility. We are able to trace the following diagram (fig. 5), by which the three curves simultaneously approach the abscissa, and are flattened in such a manner that the vertices disappear the first.

FIG. 5.



As is readily observed, green is then precisely the color which, being ordinarily the most whitish of the primitive colors, is the first to lose its quality of "saturated" color, and shades into gray. This must then be the exact scheme of pathological color-blindness, according to the theory. In fact, we have found in our examinations a large number of cases perfectly harmonizing with this scheme. We have, therefore, classed them under the head of *incomplete color-blindness;* and this from essentially practical reasons. To define their nature according to the theory, it is necessary to regard them as a particular variety, which we shall call a *feeble sense of colors.* We are not of course able to decide how far defects of this kind should be considered as having a pathological origin, or whether they are ever congenital. For this determination a much wider experience in this particular department than we now possess is requisite, for reasons to be given hereafter. This kind of defect in the sense of color leads, if we fancy it carried to its highest degree, or in such a condition that all the elements lose sensibility, to the complete absence of perception of light, that is to say, to blindness, strictly so called. Every defect in the sense of color must then proceed either from a sensibility anomalously reduced to a complete paralysis of one or several kinds of elements, or from a number relatively diminished in sensibility to the complete absence of one or several amongst them.

The experience acquired by an examination of colors in different parts of the visual field elucidates our theory of color-blindness, while at the same time having a practical value. The following is the manner in which this examination is conducted: the eye is fixed upon an immovable point; a colored object—for example, a colored paper one or two centimetres (two or four-fifths of an inch) square—is slowly passed from the side of the visual field toward the fixed point. This experiment is performed still better by means of a special instrument, Förster's perimeter. We then find that the colored surface, of any color whatsoever, appears completely colorless at the extreme periphery of the visual field. Surfaces of different colors exhibit only variations in intensity of light, not in color. The ground on which the surface appears plays here an important part; since every time our visual sense perceives the light and color of an object, it partly depends upon the comparison with that which surrounds it. Thus a colored surface seems to us, in this part of the visual field, black or gray on a light ground, and gray or white on a dark. If while following the same direction, the colored object is carried within the region which surrounds the rest of the visual field, like a belt of greater or less width, we begin to see the colored object, but not always in its natural color. Two colors alone, yellow and blue, retain their natural colors. All the others have the appearance of one of these colors, consequently yellow or blue. It is only after the colored object is carried a little farther toward the fixed object that it is seen in its natural color. Consequently we normally see colors only in the middle of our visual field, within a compass extending in a more or less eccentric manner in every direction from the fixed

point. Outside of the central field extends a belt which surrounds it on all sides, and in which our whole system of colors is classed under two heads, exactly as in the case of the red-blind. We have here, as in the last case, but two colors, yellow and blue. In other words, we are completely red-blind in this intermediary zone; beyond this, there is a peripheral belt, in which we are totally color-blind. These are matters unquestionably of great theoretic value, but it must be acknowledged they are also of great practical importance. Although we have adopted the Young-Helmholtz theory, we must admit that the different kinds of perceptive elements of colors have a different local division upon the retina; and this is why we may speak of the topography of the chromatic sense. The fact is explained in this way: in the retina of the normal eye, there are simultaneously three kinds of elements in the central part, corresponding to the central region of the visual field. Toward the periphery, beginning at the central fossa, the elements become more and more rare, but in unequal proportions, so that the perceptive organs of red cease first, and this at a limit corresponding to that of the central region. In a belt which answers to the intermediate zone, or the belt of the red-blind, there remains in consequence but the perceptive elements of *green* and *violet*. At the limit near the periphery of the retina, corresponding to that of the peripheral zone of the visual field, or region of absolute color-blindness, the perceptive elements of green cease also, so that there only remains in this last zone the perceptive elements of violet. We have been especially led to this last conclusion by the examination of two cases of color-blindness, where the visual field was so abnormally small that the peripheral zone seemed to be effaced, and where we besides recognized the characteristic features of violet-blindness. This experiment, which perfectly harmonized with the theory, showed us the relation of complete red-blindness to the normal chromatic sense. Red-blindness is distinguished from the normal sight in this, that the normal central field is wanting, but is replaced by a mean corresponding at the same time to the central field and to the intermediary zone of the normal sight. We have also succeeded, owing to the peripheral investigation of the colored visual field, in verifying in a great number of cases the continuous series of forms of transition which we have classified as one kind under the head of *incomplete color-blindness*, or in the instance especially occupying us here, *incomplete red-blindness*. In the same way, the other kinds of color-blindness may also, as regards the visual field, be classified according to the theory. The visual field of the green-blind is distinguished from that of the normal observer in this, that it has a peripheral field corresponding in extension both to the intermediary and peripheral zones of the normal observer. The violet-blind is distinguished on the other hand in this, that it is completely deficient in the normal peripheral zone. These two kinds of *incomplete color-blindness* are characterized by a central field diminished at every degree. With regard to the visual field we may therefore lay down this rule, that it has as many distinct zones, with reference to the perception of colors, as the chro-

matic sense has fundamental colors or different kinds of perceptive elements, and that the different degrees of incomplete color-blindness are in the inverse ratio to the dimension of the visual field. If the central field is limited to a circle of ten degrees from the fixed point, all the respective characteristics of color-blindness are usually found in it, sometimes within even a narrower range. A feeble sense of color manifests itself in a much wider central field. All the anomalies that can be discovered in an examination of the visual field might, in consequence of the method employed, be explained by a diminution of excitability as well as of the number of the elements. The intermediary zone of the normal visual field or belt of red-blindness has an especial interest, as it furnishes us with the opportunity of seeing with our own eyes as the red-blind sees, and consequently of exactly comprehending his abnormal perception.

According to the theory, we see only yellow and blue in this belt, and in consequence we admit that the red-blind not only *call* yellow and blue their principal colors, but moreover *see* them exactly as the normal observer does. This hypothesis cannot assuredly be proved, but this is not necessary, as the explanation Helmholtz has given of the designation of one of the principal colors of the red-blind is perfectly satisfactory. This circumstance, however, has given rise, amongst others, to a doubt about the Young-Helmholtz theory, and to another theory admitting four principal colors to the normal sense of colors, yellow being classed amongst them. But this is useless. It must not be forgotten that colorless light as well as colored light are subjective perceptions, and that *comparison* here performs an important part. This fact is sufficiently proved by the phenomena of contrasts, accidental colors, etc. White is not a color; it is merely a general, neutral light, and is therefore produced when one kind of element is not more excited than another, or when all the elements are equally excited.

But as the theory obliges us to admit that the excitation of the perceptive elements of green and violet may in certain cases, as in the instance of the red-blind, supply the perception of white, and not bluish green, and that in certain cases, as in that of the green-blind, the excitation of the perceptive elements of red and violet does not give purple, but white, it is in no wise contrary to the theory to admit that the excitation of the organ perceiving green gives the perception of yellow in cases where all that remains moreover of the system of colors is the complementary color of yellow, that is to say, blue. The excitation of the perceptive organ of green gives the perception of green only on the retina or on a point of the retina which also contains the organ perceiving red. But this is not the place for further developments of this theory.

2.—CLASSIFICATION OF THE DIFFERENT KINDS OF COLOR-BLINDNESS.

In the preceding we have indicated, in conformity with the theory, the different forms of a defective sense of colors to which, we think,

should be applied the name of color-blindness, and which, owing to their nature theoretically, must be considered as of different kinds. This division will be sanctioned if we consider the relations in which it stands to the method pursued for discovering them, and which is based on the Young-Helmholtz theory. It is this we are about to explain.

We classify the different kinds of color-blindness under especial heads, to be able the better to grasp the whole. We might indeed divide this blindness into congenital and acquired, but as such a division has reference alone to the mode of origin, and not to the nature of this blindness, and affects in no wise the manner of its discovery, it has no practical importance in the case now occupying our attention. Besides, our division relates, as does our entire memoir on this subject, essentially to congenital color-blindness. The division is as follows:

I. Total color-blindness (*total fargblindhet*), in which the faculty of perceiving colors is absolutely wanting, and where the visual sense consequently can only perceive the difference between darkness and light, as well as the different degrees of intensity of light.

II. Partial color-blindness (*partiel fargblindhet*), in which the faculty of certain perceptions of color, but not of all, is wanting. It is subdivided into—

1. Complete or typical color-blindness (*fullstandig* or *typisk fargblindhet*), in which one of the three fundamental sensations, one of the three perceptive organs of color in the retina, is wanting, and in which consequently the colored visual field has but two ranges. This group includes three kinds, namely:

(*a*) Red-blindness (*red blindhet*).

(*b*) Green-blindness (*grön blindhet*).

(*c*) Violet-blindness (*violett blindhet*).

2. Incomplete color-blindness (*ofullständig fargblindhet*), where one of the three kinds of elements, or perhaps all, are inferior in excitability or in numbers to those of the normal chromatic sense. Incomplete color-blindness exhibits, like the normal sense, three zones in the visual field, but is distinguished from it by an unusually small central field. This group includes the whole of a series of different forms and degrees, a part of which—the superior degrees, which might be called *incomplete red-blindness* and *incomplete green-blindness* (and *incomplete violet-blindness*)—constitutes the transitions to the corresponding kinds of complete color-blindness, and another part of which—the inferior degrees, which we call a feeble *chromatic sense*—constitutes the transition to the normal sense of colors.

We will show further on that this classification, based entirely upon the Young-Helmholtz theory, is quite practical, and conformable to experience. We know no classification which, though distinguishing accurately between the different essential forms of a defective sense of colors, draws a surer, more decided, and more practical limit between the defective sense of colors and the normal sense.

For the classification of the different forms of the defective sense of colors, regard is generally paid to the methods of investigation, and the division is governed much more by those methods than by a theory of the sense of colors. But in every case it is found that the classification latterly in use leaves room for much improvement, either because some of the forms of defective color-sense not taken into account, or, on the other hand, because even some cases of normal chromatic sense, wanting in exercise and intelligence, have been classed amongst the different kinds of defective color-sense. As an instance of the first kind, Dr. Stilling's classification should be mentioned, which is based upon the theory of the four primitive colors, complementary two by two. According to it, there could be but two kinds of color-blindness, namely: "*rothgrünblindhet*" and "*gelbblaublindheit*" (*green-red-blindness* and that of *blue-yellow*). Without allowing ourselves to criticise the theory itself here, we will simply remark, looking at it practically, that, on one side, this classification draws no distinction between the various kinds of red- and green-blindness, Dr. Stilling classing them as one, and that, on the other side, the whole series of forms classed by us under the head of incomplete color-blindness is not included in his plan.

As an example of a classification of the last kind, the one which seems universal in France, and employed by Dr. Favre and Dr. Féris, may be cited. It is reduced nearly to this: all those who give false names to the primitive colors belong to one class; those who are only mistaken in the shades, but not in the principal colors, are classed under another; and, finally, those who, after several trials, evince some hesitation in designating colors, form a third class. It is plain that this classification gives but little idea, properly speaking, of the nature of the different kinds, and that the third class must include a large number of individuals endowed with normal sight, but who have been mistaken or hesitated at the time of the test, in consequence of want of exercise.

3.—COLOR-BLINDNESS IN PRACTICAL LIFE.

Volumes might be written on this subject, if the different instances of all the peculiarities presented by color-blindness, and all the embarrassment to which they give rise, were cited. We will limit ourselves to a few facts here, closely connected with our really practical end, and over which they exert a direct influence. To avoid being prolix, we will merely remark that in alluding to color-blindness in general, without naming one especial kind or form, we usually mean the ordinary typical kinds of partial and congenital color-blindness, namely, red and green.

We must first remember that color-blindness is not a *disease* in the sense of being attended with suffering, obliging the individual to have recourse to a physician. Color-blindness, quite as well as the normal sight, is a sense of color, though of another and a more simple nature. He whom we call color-blind is not correctly speaking at all blind to

colors. He perceives, in the main, the same kind of light as the normal observer, but sees a part of it in another manner. In the system according to which he arranges his colors, he has fewer kinds than the normal observer, and this is why he is obliged to classify under the same denomination a portion of the colors classed by the normal observer under different heads. It results from this that he finds resemblances between colors or confuses others that the normal observer finds different; for instance, red and green. These confusions naturally surprise and amuse the normal observer, who readily imagines that it arises from very great ignorance of colors, or from defective training. He ordinarily supposes that there is no limit to the mistakes the color-blind might make in this respect. But such is not the case; he obeys laws quite as exact as does the normal observer; a color-blind person can no more accustom himself to seeing colors as the normal observer does than the red-blind can see colors in the same way that the green-blind does, or conversely.

This theory, which is based upon experience, explains to us how the color-blind see colors. But if we only base our ideas on the names given to colors by the color-blind, we can be easily deceived. To judge correctly of color-blindness, and the various practical questions connected with it, it is of the highest importance to distinctly observe the difference between the manner in which the color-blind person *sees* and the manner in which he *names* colors. The sensation is based upon the nature of the sense of color in the organization of the optic nerve from birth. The *name*, on the contrary, is learned; it is conventional; it depends upon exercise and habit. The names of colors are naturally the objective expression of subjective sensations; but, on the other hand, they are regulated by the system of normal sight, and cannot consequently agree with that of the color-blind. They can, nevertheless, be learned by the latter, and even applied correctly in many cases. There is connected with this fact a peculiarity of the utmost importance practically to the question in point, and one that has given rise to the most serious embarrassments and misunderstandings. This has been and is still one of the chief causes of our erroneous ideas on the subject of color-blindness existing in the masses, because it is the veil under which this defect usually conceals itself from our observation in every-day life, and under which, even to the last moment, it will succeed in escaping discovery in cases where, as frequently happens, the methods of exploration employed are indecisive or are based upon erroneous principles.

If we reflect on the condition of the color-blind, it is difficult to understand how he can avoid being detected in his daily intercourse with men endowed with normal sight. And yet experience has sufficiently controverted this idea. That which we have acquired in examining *en masse* the *personnel* of a railway, for example, where it is required night and day to give attention to colored signals, is singularly worthy of notice. We learn by it that a number of color-blind were discovered, although

their defective sense of color had never been suspected by themselves or any one else, and the majority had correctly performed their duties. Such a condition of things furnishes us with food for reflection, and it will not be uninteresting to examine some of the peculiar circumstances which explain it. All the details connected with the subject cannot be, of course, enumerated here. We will content ourselves by merely indicating the course to be followed to obtain this explanation.

Agreeably to the property of our senses to serve as sentries before the external world, we interpret the information they give us in a particular manner. In fact, we do not consider the changes that take place in our sensitive apparatus, of which alone, however, we possess any immediate perception, but refer everything immediately to the cause that has provoked it (that is to say, to the external objects), and we attribute as qualities properly belonging to them what in truth is merely a process of our own organs. If an object simply reflects certain kinds of rays of light to our eye, we preceive a certain corresponding color, red, for example. We ascribe this perception to the object itself as an attribute, and we say it *is red.* A red carpet seen by daylight is and remains red. It is red by no matter what kind of light. It is red even when behind our backs or before our eyes in the dark. We discard the sensation of red, which belongs to our optic nerve, for the *quality* of red, which we ascribe once and forever to the carpet, and by this *name* of red we supply a whole definition, which, to be complete, should be stated nearly thus: "A red carpet is a carpet which, by the ordinary light of day, reflects only ethereal waves creating, when in contact with the retina of a normal eye, the perception of red, but absorbing, *per contra,* all the other luminous waves." It is owing to this manner of imputing qualities to objects that the name *black* has been admitted amongst the names of colors, although properly speaking it would designate the quality of absorbing all light, and consequently of not at all affecting our eye. Now the tendency to employ our senses, as we have just incidentally stated, is often promoted by a school education so limited and partial that the immediate impression is referred to the external object, and the faculty of observation is suppressed to give place to descriptions and to names.

As color is an immutable quality in a variety of objects of different colors, it is not very difficult to learn their names by heart. The direct impression is not even necessary. We may hear a really blind man, even one born blind, give the exact names to colors of common objects of which he has often heard. To the color-blind this is still more easy, as he derives some assistance from his incomplete chromatic sense. On the other hand, it must be comparatively very rare to meet one color-blind, who influenced as Dalton was by individual interest carries his reflections on colors and the chromatic sense so far as to reach the point of discovering his own anomaly. Amongst the color blind discovered by us,

while directing our researches especially to this point, not a few have been painters and tailors.

But such disregard to the subject of colors is no longer permitted in occupations where colored signals are employed and where human life may depend upon the manner in which the signal is or is not understood, as on railways and at sea.

A great number of color-blind are to be found employed in almost every position on railways, without the defect in their chromatic sense being suspected by themselves or others. Nay, more, a number of them, far from being willing to acknowledge, even after the examination, the existence of such a defect, urgently demand a new trial, even six or seven, offering all kinds of pretexts to account for their repeated failures. They all agree in declaring that they have excellent sight; that they have never had the least difficulty in distinguishing signals, though they have been employed for a long time and in the most important positions, that for instance of engineer, and had never made the slightest mistake; that the engineer is never the only one whose duty it is to watch the signals. He has always near him a fireman, and in his neighborhood an assistant engineer, a greaser, etc., who come to his aid at critical moments. That must be a very rare case where all the officials are affected with color-blindness.

Looking practically at the fact mentioned and the explanation given, it might be imagined probably that color-blindness, although a subject of scientific interest, could not possess any possible practical interest. At least, it might be believed that all the stir which has been made in our country about color-blindness amongst railway employés was founded upon nothing real. Since it is proved (it may perhaps be urged) that the color-blind have long been employed on railways and the defect never remarked, without any accident or even inconvenience resulting from it, and finally since they can really learn to distinguish signals, although otherwise than by colors, their kind of blindness should not legitimately give rise to any preventive measures whatsoever. And doubtless a great many still reason in this manner.

We will not dwell here upon what experience has or has not proved with regard to this in our country. The fact is certain that color-blindness in other countries has caused numerous and serious accidents. And even though experience should not have proved it in an absolute manner, it would not be the less evident that in such cases no one has the right to await a new experience of this kind before proceeding from words to acts, inasmuch as it can be demonstrated that, in spite of the many circumstances aiding the color-blind to obey signals, all danger is not averted, and uncertainty still remains. Now, this is not difficult to prove, for neither the fact that color-blind individuals have been long employed on railways without causing accidents, or without the discovery of the defect, nor the circumstances we have cited to explain this fact, furnish the slightest ground for security.

A color-blind individual of the typical kinds cannot distinguish red from green. This is an undoubted fact, easily explained by theory and adequately proved by experience. All that he asserts about differences between these colors is founded consequently upon conjecture. But this manner of perceiving signals is attended by great uncertainty, and he who guesses correctly in this manner in a certain number of special cases must infallibly guess wrong in some cases. This is a principle which does not rest on a theory, but which has been confirmed by our experience without an exception in an examination of more than two hundred color-blind persons, and its evidence could be extended far beyond the limits to which we are confined here, or, in other words, to the majority of the cases of incomplete color-blindness.

If a small amount of soot, smoke, vapor, ice, snow, etc., adhere to the glass, the lantern shines less brightly. A lantern shines differently in clear or foggy weather, etc. All this may give rise to mistakes. But, on the other hand, the sensibility of the eye is very different according to circumstances. The nervous organ of the eye may, like every other part of the system, vary extremely in sensibility. The same light is to the sound and rested eye stronger than to the weak and tired eye, etc. But every modification of intensity of light is equivalent, to the color-blind, to a change of color. All this proves how little reliance can be placed upon the knowledge of signals acquired by the color-blind by practice.

III.—REFORMS RELATING TO COLOR-BLINDNESS.

As we have shown already, the tendency of color-blindness to conceal itself wheresoever it occurs, in all classes of society, especially in the lower, may be regarded as one of its most remarkable peculiarities. It is necessary to add still another circumstance: one whose color-blindness has been disclosed, and who is thus himself made aware of his defect, and who has been, as is so commonly the case, a subject of ridicule to his acquaintances, is generally more than ever eager to conceal his infirmity. The result of this is, in spite of all that has been written on color-blindness, this affection of the sight, far from being recognized as a fact belonging to every-day life, has been and still is considered by the public as a legend about which anything desired could be believed. The idea, at least, usually formed with regard to its frequency and practical importance, is far from corresponding with the reality. It is difficult to accustom one's self to the idea of the necessity of refusing to a number of persons admission to a career which would afford them means of subsistence, and, what is worse, to discharge from their present position those who have performed their duties in an irreproachable manner, and which have been to them and their families a legitimate source of income.

Prompted by a just regard for the good of man, it is asked whether

the difficulty in distinguishing colors experienced by certain individuals may be corrected by exercise. And if this is not possible, it is natural to conclude that more regard is due to the men than to a particular kind of signals, since the latter is not absolutely essential, and consequently may be changed if not adapted to the employés.

1.—INSTRUCTION AND EXERCISE OF THE PERSONNEL IN RECOGNIZING COLORS.

The importance of the habitual exercise of our senses generally should not be underrated. As we are born with naturally sound organs of locomotion, and yet require to be taught to walk, so it is necessary to learn to use our organs of sense; and when experience shows us that many original defects of our organs of locomotion can be remedied as well as those of our visual organs, we readily conceive the idea that this is also possible with color-blindness. If it were the case, this would be, without doubt, the most radical means possible for protecting railway lines, without the necessity of displacing a single employé.

To avoid all misunderstanding, we must dwell upon the difference that we have mentioned between the genuine *perception* of the color-blind and the *name* he gives to the color of the objects. We have already seen that a true name may often be united to a false perception, but it is evident, also, that just as the perception is anomalous, or merely uncertain, the name must also be uncertain, as it is simply a conjecture. We do not here allude to that *acquired* color-blindness which, casually occurring, might also disappear, but to congenital color-blindness, let it be understood.

We will endeavor to give some account here of what experience has furnished on this subject, and first of all we will try to discover upon what grounds it is claimed that color-blindness can be cured.

An effort has been made to derive one indication of this from the fact that amongst the numerous instances of color-blindness that have been discovered and mentioned by different writers since Huddart, there are many more amongst men than women. It is concluded from this, in the first place, that color-blindness is much more common amongst men than women, and from this statistical fact, added to the undoubted experience that women have more to do with colors from their very infancy than men, from the nature of their clothing, etc., another inference is reached, namely, that exercise assists in diminishing and counteracting color-blindness. All this may be true, but the argument fails in more than one particular. In the first place, it has not been at all proved, we think, that color-blindness is less common among women than men. The majority of the cases of color-blindness described by writers have been accidentally discovered, that is to say, without any special examination. If we observe, first of all, that these are probably the most marked cases of color-blindness, and also that they are usually not persons who have much to do with colors (as these easily conceal their defect), it will be

readily understood why the female sex has furnished so small a proportion to statistics. Again, in cases where experiments are made to discover color-blindness, it is evidently much easier to find opportunities to examine men than women. For the most part, those examined are soldiers, students, agents of police, etc., it being difficult to find equal opportunities for examining women *en masse*. It is necessary to operate on a large number to obtain very satisfactory statistics. The data we possess are furnished mainly by experiments among men. This is why we venture to dispute what is usually admitted as a certain fact, that color-blindness is more common among men than women, the necessary information being so far wanting to establish such a fact. We must not overlook the testimony of Prof. H. Dor on this subject, who examined the very considerable number of 611 women at Berlin, amongst whom he found only five color-blind, or little less, therefore, than 1 per cent., or exactly 0.82 per cent. We do not desire in the least to deny the possibility that color-blindness amongst women is less common; on the contrary, we think it even probable that this may be the case.

In using the statistics of the experiments thus far made on women, it is important to observe carefully whether the method of scrutiny has been such that previous exercise has not had some effect upon the result. For if the method is founded upon the principle that those examined must be interrogated as to the names of the colored objects presented to them, and their chromatic sense judged according to the answer, it is clear that the proportion of failures will be relatively less amongst women than men, as they have much more practice. We are not certain that this may not be the explanation of the result thus far obtained.

For a number of years, Dr. Favre devoted himself to the study of color-blindness amongst railway employés, and succeeded in introducing reformatory measures on several railways in France. This circumstance, and the manner, also, in which he has treated this subject from several points of view, are more worthy of attention, since he has boldly pronounced in favor of the curability of color-blindness by exercise, and urged measures founded upon this principle. We will give his result in the author's own words:

"Out of one hundred and forty-six scholars, from seven to sixteen years of age, belonging to two schools, one hundred and eleven named the natural colors without error or hesitation; thirty-five made mistakes in different degrees; twelve made serious mistakes with regard to several colors; the errors of the others were with regard to orange, blue, or violet; some were mistaken about all these three colors, others about two, and some only about violet. These thirty-five children were subjected by their instructors to repeated methodical exercises according to the directions I had given them. One of the teachers cured all his defective pupils; the duration of the treatment varying from two weeks to six months. The other teacher had on the 2d of April of this year only two patients out of eleven uncured."

In an additional note, he adds: "This account of the treatment of color-blindness must be brief on account of the object for which it is intended; but it may be necessary to set forth in a few words the process in use in schools. I have simplified it as much as possible. The chief point was to have the colors corresponding with those of the solar spectrum, that is, those generally designated by the names of *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, and *red*. The scale of colored wools that I presented in large quantities to managers and agents of railways, to my colleagues, to several teachers, male and female, and to individuals under treatment, was thus arranged: five packages were composed of three shades each—three shades of *red;* three of *yellow*, including *orange;* three of *green;* three of *blue*, including *indigo;* three of *violet;* and besides one package of white and one of black wool. The children are summoned one after the other, and separately interrogated. The examination of those who are without this defect, and are well trained, is soon made. Those who hesitate or trip should be treated with great indulgence, and set straight, if I may so express it, and if their errors are not easily corrected, their answers are accurately noted down. The master then, in another lesson, shows and names the colors to the children, and makes them *repeat with him*. It is important not to make the inexpert pupil an object of ridicule or even of attention to his companions. The lesson should be repeated every three or four days until he is quite certain that the idea of colors is well established. The training is completed by making them name the color of the various objects within reach of the master; flowers, fabrics, geographical maps, etc. Our pupils will not be able to distinguish the 14,420 tints established by M. Chevreul, but they will have acquired the indispensable mimimum; they will know the *a*, *b*, *c*, of the science of colors."

What we have just quoted cannot essentially change the view we have adopted and described in the preceding pages. To demonstrate the curability of color-blindness, it is indispensable to prove, first, that the treatment is applied to those whose deficiency has been duly established, and, in the second place, that these same at the end of the treatment have a normal chromatic sense, or at least are not color-blind.

Dr. Favre's pamphlet does not furnish us on these points with sufficient evidence. We cannot, from our point of view, have much confidence in the method of investigation employed by Dr. Favre. It is not only possible, but even extremely probable, that ignorance and a want of practice might pass for color-blindness, and especially as the examination is that of children. That there were among the individuals under Dr. Favre's treatment some cases of genuine color-blindness would appear from the fact that two children, a year after beginning the training, had not succeeded in learning the task imposed, which nevertheless does not seem to present insurmountable difficulties, even in instances of persons really color-blind.

In brief, without attempting to deny the curability of color-blindness

theoretically or practically, we maintain that not one positive proof of it has so far been produced.

It is a significant fact that individuals who have themselves discovered their own chromatic blindness, and have been very much interested in it, having reflected and experimented, and consequently exercised themselves much in colors, have nevertheless retained their anomalous perception, such as it was in the beginning, for many years, indeed, as long as they lived. Such was the case with Harris, who himself discovered his defect at the age of four years, and studied it with much interest, but never succeeded in correcting it. Milne was found by Wilson to be as color-blind at Edinburgh in 1854 as he was thirty years before, when Combe examined him. Such was also the case with Professor N——, examined twenty years before by Sir David Brewster. But such was especially Dalton's case, who has thrown much light upon the subject. No one will deny that if exercise in colors can cure chromatic blindness, Dalton would have been cured, and yet it must be acknowledged that at the meeting of the British Association at Oxford in 1832 he then compared a scarlet red to the leaves of trees, proving him to be as color-blind as in 1792, the date of the discovery of his color-blindness, and as far as his friends could observe he continued so to the end of his life (1844).

The history of science tells us of cases of persons completely blind who can easily and correctly distinguish wool of different colors by means of other senses, smell, taste, or touch. The power of touch in this case deserves especial attention, as it is exactly adapted to the kind of qualities now interesting us. The close connection between touch and sight in determining whether an object is smooth, rough, etc., is well known. The assistance which these two senses render each other in a general appreciation of everything in space is not less well known. These are the very qualities, beyond any doubt, that the color-blind call to their aid to supply the place of colors. This is why many color-blind are seen placing the samples of wool in different lights, bringing them quite close to the eye and in different angles to the visual axis. But we have heard many color-blind, who knew the difference between red and green, or purple and green, frankly acknowledge that they only recognized them because one colored wool was coarser, harsher, or rougher than the other. Consequently it is not the color, that is, the quality of the reflected light, but the coloring matter and its peculiar effects upon the wool, which were to them the distinguishing features. As the result of our investigation we can state that exercise is certainly not without value, but is more useful in other respects than in curing color-blindness, or in removing the causes of the mistakes made by the color-blind with regard to the colors of signals. We maintain, therefore, that not one case has been sufficiently established to prove that a genuine case of color-blindness has ever been cured by exercise.

But it in no wise follows, we repeat, that we deny the possibility of

improvement in cases where the corresponding organs are not wanting, but are simply deficient in sensibility. Moreover, we are very much indebted to Dr. Favre for having interested himself in the question of the treatment of congenital color-blindness, and also for having undertaken the work of applying this treatment. If this idea is generally admitted, it will, without any doubt, produce excellent fruits, among others that of introducing examinations into schools, so that color-blindness will be discovered in time to be cured, if that is really possible, or if not, that its subjects may be enabled to choose a career in which their infirmity will not be attended by inconvenience or danger. This is, moreover, the only means by which we can reach a perfectly decisive answer to the extremely important question, whether or to what degree color-blindness may be improved or cured. But it is also evident that the more important the answer to this question, practically, the more does its solution require critical methods and rigid investigation and control in order that when the answer is once obtained no doubt may be cast upon its accuracy.

On the other hand, we oppose in the most positive manner every measure relating to railway officials, sailors, etc., founded upon the idea of the curability of color-blindness, until this question has been perfectly established by an affirmative answer. It is evident that otherwise not only is the danger of employing the color-blind on railways, etc., not diminished, but also that the introduction of a radical reform in this matter is impeded. When Dr. Favre requests that the *personnel* on railways and in the navy, etc., be exercised in distinguishing colors, this demand, favorably received, can only lead to the admission of the color-blind to the positions in question; and then under the assurance that their congenital defect may be cured, they are watched over until they acquire the necessary amount of training. According to our opinion, such a measure is positively dangerous, because it merely lulls the authorities with the belief that the color-blind can cause no accident, while in reality their defect is exactly where it was before, and, owing to the exercise, has only become more difficult to detect, if for this purpose a defective method is adopted. From this point of view it is apparent that exercise, far from removing the danger, only increases it. It may be answered indeed that, owing to exercise, the color-blind will less frequently confound the signals than they will without exercise, and this we willingly grant. But, on the other side, it is evident there should be no question here of an alleviation, but of a radical correction. The danger of employing the color-blind on railways or at sea once well established, it is necessary, it seems to us, to take measures for completely removing the danger, if possible. If comparative security can satisfy, we already have it, either from the fact that all the officials cannot be color-blind, or that the majority of such do not usually cause accidents. But it is precisely the desire to save the communications from this state of uncertainty that has inspired us with the idea of taking measures against it, and we believe that we have proved by what we have said that

any reform that can be introduced at present in this matter should be established just as if it were already decisively proved that color-blindness is incurable. It is therefore this hypothesis that we intend to apply in what follows.

2.—MODIFICATION OF THE SIGNAL SYSTEM.

(*a*) *Other colors for signals.*—If congenital color-blindness is incurable, or at least if we know no actual remedy for it, it is necessary to devise some other method (while retaining the color-blind in the employment of railways) of guaranteeing the communications against any mistakes they might commit with regard to signals. It is seen by what precedes that these errors can and must occur in the use of the signal colors generally adopted, *red*, *green* (and *yellow*). This choice seems therefore unfortunate. Wilson is of the same opinion. When red and green color-blindness are the kinds of complete or typical partial blindness which are most generally seen, it would seem that the difficulty might be considerably diminished, if, in place of using the actual colors, those should be selected best suited to these kinds of color-blindness, although they might not suit the third kind of typical partial color-blindness or violet-blindness, which, according to the experience acquired up to the present time, is much more uncommon.

Undoubtedly, the principle we have endeavored to establish would not be radically enforced, but the practical result at least would be comparatively nearly accomplished. As the color-blind has but two principal colors, or two classes to which he can refer all the colors, it is evident that to select two colors that he can recognize and distinguish without the least hesitation, it would be necessary to select one from each class. In this way, it is always possible to bear in mind that each kind of color-blindness will always be able to find two colors distinctly defined, but not more than two. It is therefore necessary first to ask how far two colors for signals could satisfy the demands of railways and the navy. As regards railways, it is claimed, and it may be conceded, that, in case of necessity, and perhaps without too great inconvenience, two colors might be made to answer. It is certain that three colors are a great improvement upon two. Let us admit, however, that two colors would answer, and that it were desired to sacrifice the advantage of three colors for another advantage, namely, that of retaining in the service of railways the color-blind, there will still remain the necessity of making a good selection of these two colors. This is more easily said than done. The choice must be so made that one color may be selected from each of the two groups in which all the colors are classed according to the system for the color-blind. Now, it is found, as we have already seen in the instances of the principal colors of the red and green blind, that, amongst the seven colors of the rainbow perceptible to the normal observer, four, namely, red, orange, yellow, and green, belong to one class, and three, especially blue, indigo, and violet, to the second. Consequently, one of the colors

must be red, orange, yellow, or green, and the other blue, indigo, or violet. It should very naturally be our object to give the preference in the selection to the colors which most strongly affect the eye at the time of the comparison. Now, the most intense colors of the spectrum, that is to say, the most vivid colors which enter into the white light of the sun, are yellow and blue, one of each of the two groups. We then select them, the more willingly, that the light of the lantern is, without any preparation, and to a very high degree, yellow, though it is not homogeneous. But we are far from being so fortunate with regard to blue. We here encounter a difficulty, on the contrary, which induces us to doubt whether a change of colors will accomplish the desired end.

On all colored surfaces—flags, paintings, semaphores, etc.—employed by railways to reflect during the day the sunlight or daylight, the proposed colors answer perfectly without any doubt, and, in all probability, no color-blind individual of the kinds specified would nominally make mistakes of judgment. But the night-signals are quite another matter, and are by far more important for many reasons. This is therefore why we prefer to attach here so much importance to them, as during the day a multitude of different circumstances might give warning of danger, while during the night the colored light is the only signal which indicates it.

The colored lights used for night-signals are made, as all know, by placing colored glass before the flame of a lantern. The use of Bengal lights as regular signals could scarcely be introduced into practice. Now, a colored glass produces a colored light, because, of all the kinds of light radiated from the flame, but one kind (or, at least, mainly one kind) is allowed to escape, while all the others, or a greater part of the others, are absorbed by the glass. Thus, blue glass, according to its thickness or degree of coloring, absorbs all the other kinds of light emitted by the flame of the lantern, allowing only the blue rays to escape. But, unfortunately, as is well known by direct experience, the flame of the lantern emits comparatively but a small amount of blue light when rape-seed oil and photogene, or generally any of our ordinary sources of artificial light, are employed; and this is why all appear yellow or red when compared with the light of day. Under such circumstances, blue glass can naturally transmit only a small amount of blue light; and the light of a blue lantern must consequently always be very feebly luminous.

What we have just said of blue applies equally to indigo and violet. The proposed changes of the colors of signals furnishes, therefore, but two colors in place of three; and then one is a very feeble light, so that it is difficult to see it far off so long as it is sufficiently colored. This state of things scarcely holds out much inducement to introduce a reform of this nature. And it seems the more dangerous that this change of colors in the signals would cause those with normal sight amongst the *personnel* to run the same risk that the really color-blind do; I mean that

they would be forced to distinguish and judge the night-signals alone by the intensity of the light.

The result of all that we have just said is, it seems to us, that the proposed change of the signal colors is not very practical, and such would be the case with any other choice of two colors. It must at least be conceded that the new signal colors would be to every normal observer worse than those now in use with us, as with nearly all nations; in brief, if they were adopted, it would diminish the public safety. We must add that, by adopting them, the principle we have explained is not taken into consideration, according to which it is necessary to use a system of signals adapted to all kinds of color-blindness, since the violet-blind are not able to distinguish between yellow and blue. The proposed change should therefore be rejected, it seems to us, on every practical consideration.

(*b*) *Colorless light and darkness, black and white.*—It has been seen that it is impossible to hope for colored signals suiting every one, color-blind or not; it becomes necessary, therefore, to try to devise a plan for establishing a system of signals independent of colors, and based upon the introduction of a colorless light of different degrees of intensity. While there is nothing more sensible to our sight than the relative intensity of two lights placed side by side (when the absolute intensity does not exceed certain limits), in the present case the only comparison involved is made from memory, so to speak, which is equivalent almost to an appreciation of the absolute intensity of light. We are so far from being able to judge of this, that, in spite of a deeply felt need and constant efforts, science even has not succeeded in discovering suitable measures to apply to it.

It is, however, necessary to acknowledge here that a system of signals based only on two extremes of intensity of light, namely, on light and darkness, white and black, ought to suit the normal observer as well as the color-blind. Moreover, such a system ought to satisfy all exigencies, provided it is practically applied, and that two signals only are sufficient. A white and black flag, etc., would fully suffice during the day; but such would unfortunately not be the case at night, for a black light is a contradiction of terms, and it would be necessary, consequently, according to this system for the night, when signals are of the greatest importance, to be limited not to three, but to one signal only, unless the absence of all signals could be considered as one. Here it might be well asked, whether the better system is not that which is based on the alternations of darkness and light, that is, movable signals or eclipsed signal-lights. As far as we know, no system has yet been discovered, based upon the principles alluded to above, which could advantageously take the place of the one actually in use.

(*c*) *Form, movement, number.*—If we do not succeed in finding a suitable system of signals, based on the differences of the quality and quantity of light, there remains but to appeal to some arrangement in space,

if absolutely limited to the visual sense. Many different ways suggest themselves of varying the signals by form and arrangement in space: large brilliant surfaces arranged in different forms; several small lights grouped in different positions with reference to each other; lights simply disposed, but differing in value as signals according to their number, or else illuminated figures of simple colors, and produced by different movements, and so on. A practical difficulty seems to be connected with such a system; the signals require the illuminated surfaces to be large enough, or placed at distances considerable enough between the luminous points, to appear distinctly afar off; now the larger such a figure, having the outlines marked with luminous points, the greater the risk that a portion of it be hidden by other objects intervening between it and the eye. These two inconveniences must be apparent, particularly if these surfaces and illuminated figures have to be placed at every point where colored lanterns are found, as for example on locomotives and cars.

If the system of signals were based upon form, and all persons discharged from the service of railways who, in consequence of an imperfection of vision, could not clearly and decidedly distinguish these signals at a distance, the proportion of such would be larger than that of the color-blind. To form an idea of the different capacities of the normal eye in the various senses just mentioned, we will recommend a very simple experiment. Take something, colored paper, for example; make some plain figures, such as letters, one of which must be attached vertically to a large black or white surface. To prevent any distraction from subjective influences, let some one else select and attach this letter, while the observer stands at such a distance that even with the eye directed toward it but a single object can be seen. If the letters are small, it is not necessary that the distance should be very great. Then if the symbol be slowly approached, with the eye fixed on the colored surface, the following observations in the order in which the different impressions succeed each other will be made. When the letter is first perceived, neither form nor color can be distinguished; nothing is seen but a point or patch darker than the background, if that be white, or lighter, if it be black. The first attribute remarked, as the distance diminishes, is its color. When the color is very distinct, it is necessary to approach considerably nearer before the form is perceptible, that is to say, before this letter can be read, and its name given. This simple experiment clearly shows that the eye, as far as it is possible to compare its capacities in different directions, is first sensible to the relative intensity of light, then to color, and finally to form. It would be necessary, of course, to consider various circumstances relative to the choice of color, form, etc., if the experiment should be made with exactness to serve as a basis for a scientific demonstration. It would appear therefore that a system of signals based on the power of distinguishing light from darkness is less suitable than the one now in use; not only because this is based upon

the principle of the difference in the quality of light, that is to say, on color, but because, in the application, the very colors have been chosen which in practice are the best adapted to the object in view. Experience also seems to have decided in favor of this system, since in spite of the substitutes proposed with a view to retain the color-blind, it has up to the present time maintained its ascendency, so to speak, throughout the entire world.

3.—DISMISSAL OF THE COLOR-BLIND.

It now remains to solve the question of what reform is preferable. Is it necessary, in order to facilitate the free admission of all classes of color-blind to the service of railways, to change a system of signals recognized as the best and generally accepted, or, continuing the system, to discard the incompetent? It is manifest, from what we have just said, which measure is most conducive to the safety of railway lines. All depends upon knowing whether, from solicitude for the color-blind, any measures tending to diminish systematically or on principle this security should be countenanced. We are fortunately accustomed to accepting the maxim that private interest must yield to the general welfare. The proportion of color-blindness in the population of a country is relatively very small. It is true that railway employés are not made for signals, but the signals for them; yet it is no less certain that in this matter the first consideration must be the public good, and not a personal advantage. It is, without doubt, very praiseworthy to desire that any one afflicted with a congenital defect, for which he is not responsible, should not be debarred from entering every career open to those more favored by nature. But this case is not peculiar, for there are many other careers to which every one has not access for want of the natural ability requisite for the efficient discharge of the duty; and there are numbers of persons who, in consequence of some natural defect, cannot be admitted into even the most common occupations. We will, therefore, maintain the position that, as long as the existing system of signals used on railways is considered in almost all respects the best known, it is indispensable that no one incapable of rapidly and accurately distinguishing red, green, and yellow should be allowed to fill any position on railways involving any connection with colored signals.

IV.—GENERAL PRINCIPLES AND PLAN OF CONTROL OF THE CHROMATIC SENSE.

It is, of course, to the interest of railways not to take into their service persons having any degree of defect in their chromatic sense. It must be acknowledged that in several posts on railways, the observation of signals is not considered an indispensable requisite; but as it is, at least, unfortunate to have an employé who *can* not, in case of need, attend to the signals, we consider this reason alone as quite sufficient. For no one,

and still less a color-blind individual, could be regarded as born especially for a railway employé. Numerous other vocations are open to the color-blind, although they might, on account of this defect, run the risk of finding themselves excluded from many occupations where color-blindness is much less injurious than to railways. Hence, we conclude that the decision to be adopted in this matter must be comparatively very stringent, that is to say, *that a relatively slight defect of the chromatic sense must suffice to prohibit admission to the service of railways.*

The question is quite a different one with respect to those already employed on railways, and other points must be weighed. It may be necessary, perhaps, to remove them from a position which suits them, and where they have earned a livelihood, and performed their duties in the most irreproachable and decorous manner. *It is just, therefore, that the least severe principles be applied, and their personal interests as much as possible considered without violating the requirements for the safety of the line.*

In this case, no one should be dismissed without plausible reasons, and when any such exist, the employés to be discharged should be treated with as much consideration as possible, and receive a legitimate compensation for their loss by the offer of another place or a pension.

In order to secure an intelligent supervision and control, each employé should submit to a rigorous examination of the chromatic sense, that there might not be the slightest doubt as to the nature of its capacity. To be able to attain this end in a perfectly certain and at the same time practical manner, while creating as few difficulties as possible, is without doubt the most difficult part of the reform to execute. It is admitted as a fact that color-blindness may manifest itself in persons formerly endowed with a perfectly normal chromatic sense. This is what is called acquired or pathological color-blindness, only lately known, and far from being as much studied as the congenital defect. It would be perhaps more suitable for our practical purpose to divide pathological color-blindness into two classes, one of which might be called *general* or *regular*, and the other *local* or *irregular*. We will understand, by the first term, that kind of pathological blindness due to general causes, and usually concentrically disposed about the yellow spot; and, by the second, that which is produced by local causes, and appears eccentrically placed in the visual field, or having its center in the blind spot. This last class should not belong to the subdivision now occupying us, principally because it rarely appears in such a degree as to be able to occasion any danger to railways. There is no doubt but that this acquired blindness really exists. Dr. Favre and several other writers have especially devoted themselves to this form of color-blindness amongst railway employés; they have pointed out several causes to which it is due, and proposed measures for discovering it. It is of the highest importance here, it seems to us, that perfectly certain methods of investigation should be employed. Dr. Stilling justly remarks that the great frequency of congenital color-blindness constitutes one of the principal difficulties encountered in obtaining an

accurate knowledge of pathological blindness. It is also plain that in cases where pathological color-blindness might be confounded with congenital blindness, there is no means of arriving at a knowledge of its true nature, unless in an individual who, after a rigid examination previously made by a trustworthy method, had been found to possess a normal sense of vision. But it can scarcely be admitted that there have been any such cases amongst those hitherto cited. But there is no better way of definitely solving this question than by systematically organizing observations and repeated examinations on railways where all the *personnel* have been previously examined. On this point, among many others, the interests of science and those of the public go hand in hand.

Within the last few years sufficiently positive information has been gathered to be able to form a fixed plan for enlarging these examinations. Dr. Favre tells us—according to his experience and that of several of his colleagues—that common causes of color-blindness are contusions, serious illnesses, such as typhoid fever, etc., and the abuse of strong liquors.

After every accident by rail or at sea, from collision, etc., where mistakes in distinguishing colors have been the principal or secondary causes, not only the *personnel* present at the time of the accident, but also all who have to give testimony about the signals, should be subjected to a rigorous examination. The necessity of this measure must be evident from what has been said before. It is absurd to condemn any one because some one who is blind says he has *seen* him violate the law, or to exculpate him because the blind person has *seen* him fulfill this law. To solve the problems involved, it is necessary to make periodic examinations, 1st, of every one who has a chromatic sense already acknowledged as defective; 2d, of all who have had contusions, etc.; and, 3d, of the whole *personnel*, to discover any color-blindness that may have arisen without apparent cause. The result of all that has been said is, that it is absolutely necessary that the directors and principals should be perfectly familiar with the nature of the chromatic sense of each one of their subordinates.

V.—SHORT CRITICISM OF THE USUAL METHODS OF INVESTIGATION.

Our exposition of color-blindness has shown, we hope, that, in spite of its wide divergence from the normal chromatic sense, it is not so easily discovered as one might imagine; quite the contrary. Just in proportion to the increase of our knowledge of color-blindness and the peculiarities of its subjects have we been led to establish different methods for its discovery. Several already exist, which differ from each other in the very principle upon which they rest or in the application of this principle.

Supposing the usual signal-lights be presented, one after the other,

to the person examined, he being required to name the colors or their value as signals, his chromatic sense could not be judged by his answer. For we have seen, on one side, that the color-blind *can* guess correctly in such cases, and, on the other hand, it is scarcely necessary to say that the normal observer might make a mistake in the name, either from negligence, through inattention, or simply by a *lapsus linguæ*. How many times, then, must the trial be repeated to secure positive results? How often must the individual make mistakes to be considered color-blind? How many times may he make them without being considered color-blind? Evidently there is no categorical answer to these questions. We are therefore authorized to conclude that the examination by means of railway-lanterns, for discovering color-blindness, must be considered for several essential reasons as an impracticable method, and consequently to be rejected. The use of flags, for the same purpose, is still worse. A general principle, applying to every examination of the chromatic sense, is that such examination should not at first endeavor to trace the connection of the chromatic sense with signals of any kind whatsoever, but have in view only the discovery as to whether the subject *is or is not color-blind*, or whether the *chromatic sense is defective or normal.* While none of the various methods proposed can be condemned as absolutely barren, there are several which, used alone, never give positive results, or give them only in a limited number of cases, or else cause so great a loss of time, and are so inconvenient, that they ought to be rejected from this consideration alone. We class amongst these methods all those which, as in the examination by means of the lantern, have a tendency, in principle, to place before the one to be examined different colors or colored objects to be named by him. The real question is not to discover the degree of skill comparatively attained by each one in correctly naming the colors, but the manner in which he sees them, or, in other words, the nature of his chromatic sense. Any method fulfilling this requirement must, in principle, be based upon the *comparison* between different colors, and an investigation into the causes of the confusion of the color-blind about several of them.

An example will more clearly illustrate our idea and show its importance. Let us take a green-blind individual; we know by experience that he confuses or finds a perfect resemblance between the shades of three colors very different to the normal eye. I allude to purple, green, and gray. The reason of this is very simple according to the theory; the green-blind is void of the organ for perceiving green. Purple, green, and gray are, in reality, the same color to the eye of the green-blind, but he has heard three names given to these colors under different circumstances. The result of this will be that he will in his turn designate this color sometimes by one and sometimes by another of these names, or else he will only use one, especially the one he first remarked or heard most frequently applied to this color. If the subject use all three names, he will apply them correctly in some instances and incorrectly in others.

But if he employ a single name, it might in a consequent manner be, according to the case, *purple* (improperly called red), *green*, or *gray*. Supposing that he uses "green," according to the denominating method, his chromatic sense will be judged as imperfect for *purple* and for *gray*, but as correct for *green*.

From our point of view, therefore, Dr. Favre's method does not seem satisfactory. Besides, not appearing to us certain, and not supplying us with any basis for a useful classification, it requires more time than is expedient; nevertheless, this principle seems usually applied in France and England.

Dr. Stillings's method is also founded upon the designation of colors, and, if for no other reason, it should, we think, be condemned. This method is based upon the principle of colored shadows. Before a brilliant light in a dark room a colored glass is held, so that the light, passing through the glass, and in consequence colored by absorption, strikes a white surface, a sheet of paper for instance, at right angles. In the neighborhood of this sheet, and between it and the glass, a slender and opaque object, a pencil, say, is held in such a manner that its shadow distinctly falls upon the paper. This shadow then seems tinted with the complementary color of the glass, that is to say, it shows the different shades of purple or red if the glass is green; green or blue-green if the glass is red, etc., in accordance with the Young-Helmholtz theory. According to Dr. Stilling, the color-blind will be recognized by the fact that the shadow in question appears to him uncolored, black or gray, while to the normal observer it assumes the contrasted color, and the diagnosis is established according to the *names* applied to the colors of the shadows by the color-blind. It must be evident that his method deserves very little confidence, and that it simply depends upon a chance, whether after such a proof a normal observer may not be declared color-blind. Besides, as the judgment is based upon the name given to the colored shadow by the subject examined, it may readily happen also that a color-blind person may be declared to have normal sight, if, as is often the case, he guess the true name of the color. Briefly, then, this method is not sure under this form. This judgment is not founded merely upon theoretic reasons, but also upon a large number of direct experiments, and is also confirmed by the examples cited by Dr. Stilling himself.

It does not, however, follow that colored shadows may not be used in the examination of the chromatic sense, if so arranged that the examiner can perfectly regulate the light according to his pleasure. According to my method, with mirrors and two lights, a *comparison* between two colors may be established. The green-blind here finds, as elsewhere, a resemblance between a certain shade of green and purple, etc. As by this method the intensity of the light may be exactly regulated, the feeble perception may also be relatively determined. The experiment we have made about this declares in favor of the Young-Helmholtz

theory, but it has besides convinced us that the colored shadows are not suitable for the discovery in the first instance of color-blindness. This is the same case with Ragona Scina's method of representing complementary colors; and also that of Rose, which, practically, strongly resembles the preceding.

After having named the processes which, according to our convictions, are not suitable for the end in view, we must mention two other methods which thoroughly supply us with the information wanted. One is due to Seebeck; the other to Maxwell. They are both founded on the *comparison* of colors, and do not assume either any knowledge or any use of the names of colors, which is, we think, an essential advantage.

Maxwell's method consists in representing two colors on a rotatory disk, to be compared by the person under examination, the tints, degree of "saturation," and intensity of light of which may be changed at will. They can be modified, until, to the color-blind, they attain an absolute resemblance. The chromatic sense is then judged by its dissimilarity to that of the normal eye. It is in this that the force and accuracy of the method consist. It shows us with certainty how the subject sees the colors as compared with each other. The Young-Helmholtz theory is confirmed by Maxwell's method, as this shows us that, by the aid of only two primitive colors, we can exhaust the whole chromatic scale of the color-blind.

Seebeck's method consists in making the individual to be examined classify a number of colored objects according to their reciprocal resemblance or dissimilarity. In this way, we have at once a complete picture of the person's chromatic sense. We learn what colors he distinguishes and which he confounds. By this method, also, we can know how he sees colors in their relations to each other. But, although these two methods are *perfectly reliable*, they are not entirely suitable for a practical purpose, because they *require much time* and are very *inconvenient*,—that of Maxwell for the examiner and that of Seebeck for the examined. He who has examined a large number of color-blind by Maxwell's method knows only too well how much time this investigation consumes, in however incomplete a manner it is made. This arises from the extreme affectation of precision by the color-blind. It is not difficult for one with normal sight to point out two similar colors on the rotatory disk, because the essential point is the resemblance in the tint of the color. But the color-blind person who cannot perceive this tint requires a complete resemblance in the intensity of light or in the degree of "saturation," and in this lies the difficulty. His appreciation often depends upon the addition of a minimum of white or black, which is to him of the greatest importance, although the normal observer cannot perceive any difference. We may add that the method is very fatiguing and inconvenient to the examiner, on account of the continual changes made in the colors, and the incessant work that the rotation of the

apparatus necessitates. Finally, if we state that the apparatus is somewhat expensive, and is comparatively difficult to transport, it will suffice, it seems to us, to condemn its use as a method of the first order when it is required to make the examination on a multitude.

The method of Seebeck causes much loss of time by obliging those examined to classify a large number of colored objects. This is not an easy task for them. It not only progresses very slowly, requiring perhaps an hour, but costs much trouble and evident effort. One may obtain a tolerably clear idea of this by attempting to do the same work with the use of blue-green eyeglasses. The colors are then seen and classified very nearly as they are by the red-blind, and almost the same difficulty is experienced. Seebeck's method, however, is superior to Maxwell's in this, that it requires the subject to make an active use of his chromatic sense, while the other allows him to remain passive, and merely announce his decision. Both methods, however, require too much time to be employed with advantage for the purpose in question. But they are the best methods known to us at present.

The *perimetric exploration* with Förster's apparatus may be excellent in more than one case for examining those before examined, but it is not advisable alone and as a primitive method. It is even inapplicable to some persons; it entails much loss of time, requires much exertion on the part of the one examined, and requires an expensive instrument, which is besides very inconvenient for transportation.

It may be very interesting scientifically to use the *spectrum* for examining the color-blind; but this method is not very appropriate for practical purposes; it requires costly apparatus, and different arrangements, which render it more or less long and inconvenient. It does not enter into our plan to give an account here of all the known methods that may be used in the first inspection, or when desired to establish a test for examination. We shall limit ourselves to the examples cited, and to explain in a special chapter the method we have ourselves used, and which of all tried seems to us best adapted to the purpose.

VI.—NEW PRACTICAL METHOD FOR DISCOVERING AND DETERMINING DEFECTS OF THE CHROMATIC SENSE.

The method we are going to describe here has been employed in all the examinations of the chromatic sense of the different classes of the population which have been made in Sweden.

1.—A SHORT SKETCH OF THE GENERAL PRINCIPLES OF THE METHOD.

Theoretically, our method most resembles those of Seebeck and Maxwell, as it is based upon a *comparison* between different colors. It therefore first seeks to discover the chromatic *perception* of the subject, disregarding the *names* he gives to the colors, as generally it is not necessary he should designate the names. Our method resembles Seebeck's

most in this, that it does not require a special apparatus for preparing the necessary tints for the examination; it assumes there will be a supply of objects of different colors provided in advance. It agrees again with this method in not allowing, as Maxwell's does, the person examined to remain passive, and simply give his opinion of the resemblance or dissimilarity of the shades indicated, but requires him to discriminate and select the shades, and in consequence reveal by an act the nature of his chromatic sense. But practically our method differs essentially from Seebeck's. His certainly gives, in a certain sense, more complete results than ours by requiring the subject to thoroughly classify, in accordance with their reciprocal resemblances and dissimilarities, the various differently colored objects placed before him. A complete table of his whole system of colors is the result of this. Our method, on the contrary, requires the person examined to select, amongst a large number of variously colored objects, those alone which resemble the sample shown him by the examiner. The difference is evident. Seebeck's method is, without any doubt, preferable when the nature of the color-blindness in the aggregate is to be considered; that is, so long as this is yet unknown. His method then gives a more complete idea than ours of the nature of the color-blindness. But for our actual purpose, the main question is to discover a defect, with the entire nature of which we are acquainted in advance. Our practical mission then is evidently to discover, if possible, some certain sign which will enable us to accomplish this end by the shortest possible route. If a single proof which would detect the color-blind as certainly as if he revealed to us his entire system of colors were discovered, this would undoubtedly be the method preferred to any other, as it would accomplish the object much more quickly and easily. This is the case with our method. We are far from denying, in general, the value of a thorough examination, but we will say that it *may* sometimes be superfluous. Its practical advantage will not be very great, if at the cost of a great loss of time, and it may even be prejudicial, if, under a multitude of details, it conceal what is essential; in a word, prevents our "seeing the city on account of the houses." All this may be applied to Seebeck's method, when the object in view is the one of which we are in pursuit. Our method again endeavors to seize as rapidly as possible one or two essential characteristics while neglecting all the others. A single caudal feather of the peacock reveals whence it came; a single flower or fruit, the plant whence it was plucked; and the genus man is recognized if we can but see a face. It is only when the face is mutilated, the flowers, fruits, and caudal feather are defective, that in certain cases it is necessary to have recourse to other characteristics. Our method rests upon these principles; it also offers the same security as Seebeck's. But, as regards the time necessary to accomplish the examination, it bears nearly the same relation to that of the learned German, that a minute does to an hour. This may seem a very trifling matter at the first glance, but is in reality of immense practical importance

when a multitude of persons are to be successively examined. A simple calculation shows us in fact that an examination requiring one day by our method would require two months by Seebeck's.

It is but just to acknowledge that it was only by weighing the results obtained by Seebeck's method and following the Young-Helmholtz theory, as well as the principles we have indicated as indispensable to a practical method, that we have succeeded in formulating our own method, such as we shall explain it in what follows. We also will remark that it is very simple and easily mastered; but we think this is likewise often the case with all that is useful and practical, and that simplicity offers great advantages. We prefer this method because it seems to us more than any other to fulfill the conditions we have pointed out as necessary to a practical method, namely, certainty, rapidity, and convenience. The only inconvenience of any moment besides those it has in common with a greater part of the others is that it requires daylight. It *can* undoubtedly be used by artificial light (electrical and calcium lights, and certain arrangements of lamp-lights with blue glass), but this causes much loss of time.

After this rapid sketch of the general principles of the method, we will proceed to give its details, and shall not fail to mention generally the reasons why, amongst several possibilities, we have selected this or that process.

2.—THE MATERIAL AND ITS ARRANGEMENT.

Our method demands neither costly apparatus nor a special place for the examination. The only necessary elements are a number of variously colored objects. It consists in taking one from a number of objects promiscuously thrown together, and asking the person examined to select from amongst them all the others corresponding with the first in color. With regard to the colored objects, it of course matters little in principle what their nature is, as, in the main, the method never changes, no matter what the kind selected. But, practically, the choice is by no means a matter of indifference. Among the ordinary objects suggested, and also used for the purpose, are pieces of colored paper, glass, or silk, or Berlin wool, etc., the last of which seems to us the best, for the following reasons: One of the chief advantages of Berlin wool is, that it can be procured in all possible colors corresponding to those of the spectrum, and each in all its shades, from the darkest to the lightest. Such selections may be found in trade, and are easily procured when and where desired. It can be used at once, and without any preparation for the examination, just as delivered from the factory. A skein of Berlin wool is equally colored, not only on one or two sides, but on all, and is easily detected in the package, even though there be but one thread of it. Berlin wool is not too strongly glaring, and is, moreover, soft and manageable, and can be handled, packed, and transported as desired, without damage, and is conveniently ready for use wherever needed.

These advantages are wanting in the other colored objects suggested for use. Colored paper or silk may be used when light or dark, dull or bright colors are wanted; but they both have these inconveniences, they must first be cut into suitable pieces, and they are troublesome to handle; moreover, they are easily concealed from view, and it is necessary to stretch them carefully on a large surface to enable them to be seen without trouble. They are often glaring; they reflect, besides their particular kinds of light, a quantity of white light, which is a prominent defect, as it misleads the color-blind, who, as we know, judge of colors by the intensity of light, that is, the quantity of light, and he consequently estimates differently the color of a brilliant surface, according to the position in which it is found with regard to the eye, etc. The paper is often colored on only one side, and this gives rise to much trouble, as it is necessary to turn the pieces from one side to the other to see them in their true colors. Finally, from being so much handled, the pieces of paper or silk soon become tumbled and faded.

Colored glass, which must be in pieces, is not suitable either, from the fact that it is difficult to procure it in sufficiently great variety. It is besides troublesome to transport, easily broken, and finally inconvenient for using, because necessary to be held against the light of day, or a luminous source, in order that the color may be seen. The advantage of being able to use them by any kind of light does not counterbalance their inconveniences.

Although these are not all the objections, the preceding will suffice to prove the advantages of Berlin wool. All this applies equally well to wafers, powders, colored solutions, spools of colored thread, pieces of wood, and porcelain, especially painted for the purpose, etc.; they can all be and have been employed, but none of these objects are, in every respect, so well suited to our purpose as Berlin wool.

A selection of Berlin wool is then made, including red, orange, yellow, yellow-green, pure green, blue-green, blue, violet, purple, pink, brown, gray, several shades of each color, and at least five gradations of each tint, from the deepest to the lightest. Green and gray, several kinds each, of pink, blue, and violet, and the pale gray shades of brown, yellow, red, and pink, must especially be well represented. The choice of the material does not belong specially to our method. In fact, Seebeck suggested the use of Berlin wool, which was employed by his advice and still is at present. To us only belongs the credit of originating the manner in which it is employed. According to our method, the examiner selects from the collection of Berlin wool in a pile on a convenient table, and lays aside a skein of the especial color desired for this examination; then he requires the one examined to select the other skeins most closely resembling the color of the sample, and to place them by its side. The chromatic sense of the individual is decided by the manner in which he performs this task. The rapidity with which this examination is made does not seem to directly correspond with the nature of the chromatic

sense, but to depend finally upon the character of the person examined. One of intelligence, with a quick, practical mind, is examined in less than a minute. In this time, in fact, a normal eye could easily find the four or five skeins of the same color as the sample, and the color-blind make a sufficient number of characteristic mistakes to thoroughly establish the diagnosis. It is clear that a method such as ours affords the opportunity in connection with the investigation of the chromatic sense of learning much of all the peculiarities relating to the use of our senses. This is why we maintain the principle that it is necessary to leave to the activity of the hands the task of revealing the nature of the sensations, and to have recourse to the tongue only for verification when there is need of more information. The combination of the action of the eye and hands, which plays in general so important a part in the training and use of the senses, is also of great consequence in this examination. An attentive examiner, especially if he have already acquired some experience, can draw important conclusions from the manner in which the other executes his task, not only and directly with regard to the nature of his chromatic sense, but generally as to his intelligence and character, and especially in some cases as to his previous training and exercise in the use of colors, and his skill in recognizing them. The examination affords us also the opportunity of making psychological observations, which contribute in a great measure in giving us a clear idea of the nature of the chromatic sense. A practiced examiner can often detect color-blindness by the first gesture, and make his diagnosis before the end of the trial. He can, according to the manner in which the task is performed, form a judgment of a feeble chromatic sense in instances which are proved correct by the final result. He also can and must see whether the result is erroneous simply on account of a misunderstanding or a want of intelligence, just as he can see whether the really color-blind succeeds, in a certain degree, from much previous exercise or a considerable amount of caution. In short, the method supplies us with all necessary information, so that by an examination made with its assistance, a defective chromatic sense, no matter of what kind or in what degree, cannot escape observation. As we have already said, the principle of our method is that the test is confined to one color.

The faculty possessed by the eye of distinguishing colors and that of defining the degrees of light and color (of "saturation") are relatively very different; but these special faculties have this in common, that they have their maximum activity in a certain intermediary region of absolute intensity of light and their minimum at the two limits of this region. Just as we experience the most difficulty in distinguishing between the shades of intensity of light by a very feeble or very strong illumination, so it is difficult for us to distinguish colors slightly or strongly luminous, or the deepest and the lightest. It is, therefore, necessary to select as a suitable color for discovering a feeble chromatic sense either the light-

est or darkest shades. The well-defined kinds and degrees of a defective chromatic sense confound only colors of mean intensity. I have selected, to determine whether the chromatic sense is or is not defective, a light green (dark green may be also used), because green, according to the theory, is the whitest of the colors of the spectrum, and consequently is most easily confused with gray. For the diagnosis of the especial kinds of partial color-blindness, I have selected purple (pink), that is, the whole group of colors in which red (orange) and violet (blue) are combined in nearly equal proportions, at least in such proportions that no one sufficiently preponderates over the others, to the normal sense, so as to give its name to the combination. This is the reason for this choice. Purple occupies a singular position amongst colors; although it is a combination, it is, we know, a color, as well "saturated" as the colors of the spectrum, and might be, from this point of view, classed with them, although it is not found in the spectrum. In fact, it has been regarded as the eighth color of the spectrum, closing the circle of saturated colors. Purple is of especial importance in the examination of the color-blind, for the reason that it forms a combination of two fundamental colors—the two extreme colors—which are never confounded with each other. In fact, from a color-blind point of view, one of two things must happen, according to the theory: either it excites but one kind of perceptive organ or it excites them all. It appears then either like a simple color, that is to say, like one of the two colors of the combination, or like white (gray). Experiment has confirmed this hypothesis. Our sample colors, therefore, are the two complementary colors of each other, *green* and *purple*. In the examination of the chromatic sense of a large number of individuals, it is, of course, of importance to decide, first, whether the chromatic sense of the individual is or is not normal. It is only after establishing the existence of a defect that its nature or degree must be determined. The sample colors are, therefore, employed with more advantage in a certain order, as the test must be accomplished as a whole, according to a plan that experience has proved the surest, most rapid, and, finally, most suitable for the purpose.

3.—THE EXAMINATION AND DIAGNOSIS.

The Berlin wool is placed in a pile on a large plane surface and in broad daylight; a skein of the test color is taken from the pile and laid aside far enough from the others not to be confounded with them during the trial; and the person examined requested to select the other skeins most resembling this in color, and place them by the side of the sample. In the first place, it is necessary that he should thoroughly understand what is required of him; that is, that he should search the pile for the skeins making an impression on his chromatic sense, independent of any name he may give the color, similar to that made by the sample. The examiner should explain that resemblance in every respect is not necessary; that there are no two specimens exactly

alike; that the only question is the resemblance of the *color;* and that consequently he must endeavor to find something similar, of the same shade, something lighter and darker of the same color, etc. If the person examined cannot succeed in understanding this by a verbal explanation, we must resort to action. We must ourselves make the trial by searching with our own hands for the skeins, thereby showing in a practical manner what is meant by a shade, and then restoring the whole to the pile except the sample skein. As it would require much time to examine each individual in this way, it is advisable, when examining a large number at the same time, to instruct all at once, and moreover to ask them to attentively observe the examination of those preceding them, so as to become more familiar themselves with the process. By this, time is saved, without loss of security; for no one with a defective chromatic sense finds the correct skeins in the pile the more easily from the fact of having a moment before seen others looking for and arranging them. He makes the same characteristic mistakes; but the normal observer, on the other hand, generally accomplishes his task much better and more quickly after having seen how it must be done, and this is the advantage of our method.

The colors mentioned in this chapter are divided into two classes:

1st. The *colors for samples* (*test colors*), that is, those presented to the persons examined; and

2d. The "*colors of confusion*," that is to say, those which the color-blind selects from the heap, because he confuses them with that of the sample.

TEST I.—The *green* sample is presented. This sample should be the palest shade (the lightest) of very pure green, which is neither a yellow-green nor a blue-green to the normal eye, but fairly intermediate between the two, or at least not verging upon yellowish green.

Rule.—The examination must continue until the one examined has placed near the sample all the other skeins of the same shade, or else, with these or separately, one or several skeins of the class corresponding to the "colors of confusion," until he has sufficiently proved by his manner of doing it that he can easily and unerringly distinguish the confused colors or until he has given proof of unmistakable difficulty in accomplishing this task.

Diagnosis.—He who places beside the sample one of the "colors of confusion," that is to say, finds that it resembles the "test color," is *color blind.* He who, without being quite guilty of this confusion, evinces a manifest disposition to do so, has a *feeble chromatic sense.*

Remark.—We must remember that we cannot allow more than five colors for "confusion." But we have here in view, not *every* kind of defective color-sense, but only those important in the business of railways. The number of colors allowed is therefore sufficient, as these are the most important and most common.

TEST II.—A purple skein is presented. The color chosen must be between the deepest and lightest shades of the scale.

Rule.—The trial must be continued until the one examined has placed near the sample all or the greater part of the skeins of the same shade, or else simultaneously or separately one or several skeins of "confusion." He who selects either the light or deep shades of blue and violet (especially the deep) or the light or deep shades of one kind of green or gray inclining to blue has committed an error.

Diagnosis.—1. He who is color-blind by the first test, and who, upon the second test, selects only purple skeins, is *incompletely color-blind.*

2. He who, in the second test, selects with purple only blue and violet, or one of them, is *completely red-blind.*

3. He who, in the second test, selects with purple only green and gray, or one of them, is completely *green-blind.*

Remark.—The red-blind never ratifies the test of the green-blind, and *vice versa.* However, it happens in certain cases that the green-blind selects a violet or blue skein, but always the lightest shades. This should not affect the diagnosis. The examination may end with this test, and the diagnosis be considered as perfectly settled. It is not even necessary, practically, to decide whether the color-blindness is red or green. But to be more entirely convinced of the relation of complete color-blindness with the signal colors, and especially to convince, if necessary, the railway employés and others who are not specialists, the examination may be completed by one more trial. The one we are going to mention is not necessary to the diagnosis, and only serves to corroborate the investigation.

TEST III.—The *red* skein is presented to the subject. It is necessary to have a vivid red color like the red flag used as signals on railways.

Rule.—This test, which is applied only to those completely color-blind, should be continued until the person examined has placed beside the specimen all the skeins belonging to this shade or the greater part or else separately one or several "colors of confusion." The red-blind then chooses, besides the red, green and brown shades which, to the normal sense, seem darker than red. On the other hand, the green-blind selects opposite shades which appear lighter than red.

Remark.—Every case of complete color-blindness discovered does not always make the precise mistakes we have just mentioned in the preceding examinations. These exceptions are either instances of persons with a comparatively inferior degree of complete color-blindness, or of color-blind persons who have been exercised in the colors of signals, and who endeavor not to be discovered; they therefore usually confound at least green and brown, but even this does not always happen.

ADDITIONAL NOTE.—We have not given rules for discovering *total* color-blindness, because we have not found any cases of this kind. If any such should be found, they will be recognized, according to the theory, by a confusion of every shade having the same intensity of light. *Violet-blindness* will be recognized by a genuine confusion of purple, red, and orange in the second test. The diagnosis should be

made with discrimination. The first test often shows blue to be a "color of confusion." This may, in certain cases, be the sign of violet-blindness, but not always. We have not thought it advisable to admit defects of this kind; only the most marked cases, that other examinations establish as violet color-blindness, should be reckoned in the statistics. Finally, to acquire a desirable uniformity, it is necessary to add that in the preparatory examination, it is my habit to indicate in the journal, especially kept for that purpose, cases of *complete color-blindness* by 2 (2 R., 2 G., 2 V.), those of incomplete blindness by 1, and those of feeble chromatic sense by 0.5 (0.5 R., 0.5 G., 0.5 V.).

4.—PRACTICAL RULES AND SPECIAL DIRECTIONS FOR THE CONDUCT OF THE TRIAL.

The method, as we have said, plays an important part in an examination of this kind, not only from the principles upon which it rests, but also from the manner in which it is used. The best plan for directing how to proceed is by oral instructions and *de visu;* but here we are obliged to accomplish this by description. Now, this is always defective in some respects, especially if we wish to be brief. What has been said would evidently suffice for an intelligent and experienced physician, but it may not be superfluous to enter still further into detail to provide against any possible difficulties and loss of time. The object of the examination is to discover the nature of a person's chromatic sense. Now, as the fate of the one to be examined and that of others depend upon the correctness of the judgment pronounced by the examiner, and that this judgment should be based upon the manner in which the one examined stands the trial, it is of importance that this trial should be truly what it ought to be, a trial of the nature of the chromatic sense and nothing else, an end that will be gained if our directions are strictly followed. It is not only necessary that the examiner carefully observe them—which does not seem to us difficult—but that he also take care that the individual examined does thoroughly what is required of him. This is not always as easy as one might suppose. If it were only required to examine intelligent people, familiar with practical occupations and especially with colors, and with no other interest connected with the issue of the examination than to know whether they are color-blind or not, the examination would be uniform and mechanical. But it is required to examine people of various degrees of culture, all of whom, besides, have a personal interest in the issue of the examination. Different people act very differently during the examination for many reasons. Some submit to it without the least suspicion of their defect; others are convinced that they possess a normal sense. A few only have a consciousness or at least some suspicion of their defect. These last can often be recognized before the least examination by keeping behind the others, by attentively following the progress of the trial, but if allowed willingly remaining to the last. Some are quick; others slow. The former approach unconcernedly

and boldly; the latter with over anxiety and a certain dread. The lowest class are those who have the opposite desire, that is, to pass for color-blind, although in possession of normal sight. We will speak of these later, to enable us now to devote ourselves to those who undergo the trial in good faith, or, at least, with the desire to appear normal, even although color-blind.

In the trial it is especially desirable to confine the range of selection to the lighter shades of the test color (say green), for the trial would cause great loss of time and be less reliable if it included every shade of green. In fact, no little judgment has been exercised in the selection of the very lightest shade of the green proposed as a sample color. For it is exactly what the color-blind most readily confounds with the paler shades of gray, drab, straw, and salmon-color. If the subject were allowed to depart from the narrow limits established by the trial, it would include every shade of green, the result of which would be that he would prefer to select all the vivid shades, and thus avoid the dangerous ground where his defect would certainly be discovered. This is why it is necessary to oblige him to keep within certain limits, confining him to pure green specimens, and, for greater security, to recommend him to select especially the lightest shades. What we have just said of green applies also of course to purple.

The principle of our method is to force the one examined to reveal, himself, by an act of his own, the nature of his chromatic sense. Now, as this act must be kept within certain limits, it is evident that the examiner must direct him to a certain degree. This may present, in certain cases, some difficulty, as he will not always be guided, and does either too much or too little. In both cases, the examiner should use his influence in order to save time and gain certainty, and this is usually very easily done. This intervention is, of course, intended to put the examiner in the true path, and is accomplished in many ways according to the case in point.

We will here mention some of the expedients we have found useful:

A. *Interference during an extended selection.*—It is not always easy to confine the one examined within the limits of the method. He easily slips in the first test, for example, a yellow-green or blue-green skein among the others, and as soon as there is *one*, others follow usually, and it thus happens that, in a few moments, he has a whole handful of yellow-green, a second of blue-green, a third of both these shades at the same time. Our process has assisted us in more than one case of this kind.

(*a*) When the person examined has begun to select shades of one or several other colors than those of the sample, his ardor is arrested by taking from him the handful of skeins he has collected, and asking him whether his eye does not tell him there are one or several which do not match the others, in which case he is solicited to restore them to the pile. He then generally remarks that there is some obscuration, and proceeds in one of the following manners:

1. He rejects one after the other, the foreign shades, so that the correct remain, which is often only the sample skein. He is shown what mistake he has made. Names are used to remind him that one class of green may be yellow-green and another blue-green; and to induce him to avoid them, he is advised only to select skeins of the same shade as the specimen, although they be lighter or darker, and have neither more yellow nor blue than that. If his first error arose only from a misconception or want of practice in handling colors, he begins generally to understand what he has to do, and to do properly what is required of him.

2. Or else he selects and rejects immediately the skein of the sample itself. This proves that he sees the difference of color. He is then shown the skein as the only correct one, and asked to repeat the trial in a more correct manner. He is again put on the right track as just before, and the trial proceeds rightly, unless the error arise from a defect in the chromatic sense. Many seem, however, to experience a natural difficulty in distinguishing between yellow-green and blue-green, or the dull shades of green and blue. This difficulty is, however, more apparent than real, and is corrected usually by direct comparison. If the method requiring the name of the color to be given is used, a number of mistakes may be the result. If a skein of light green and light blue alone are presented to him, asking him to name them, he will often call blue, green, and green, blue. But if in the first case a blue skein is immediately shown him, he corrects his mistake by saying this is blue and that green. In the last case, it happens so *mutatis mutandis*. This is not the place for an explanation. It must suffice to say that the error is corrected by a direct comparison between the two colors.

There is, according to the theory, one class of the color-blind—violet-blind—who, in consequence of the nature of their chromatic sense, and, therefore, notwithstanding the comparison, cannot distinguish blue and green. But our method has nothing to do with this class of the color-blind, because such are not dangerous on railways.

(*b*) *Another process.*—If the one examined place by the side of the sample a shade, for instance, of yellow-green, the examiner places near this another shade, in which there is more yellow, or even a pure yellow, remarking at the same time that if the first suit, the last must also. The other usually dissents from this. He is then shown, by selecting and classing the intermediate shades, that there is a gradation which will diverge widely if logically carried out as he has begun. The same course is followed with colors of the blue shades, if the blue-green were first selected. He sees the successive gradations, and goes through with this test perfectly if his chromatic sense is correct.

To ascertain further whether he notices these additions, or the tints of yellow and blue in the green, we can take ourselves the yellow-green and blue-green to ask him if he finds this to be so. We can judge by his answer of his sense with regard to these shades, and the object of this investigation is accomplished.

It results from all this that many who are finally considered to have a normal chromatic sense may occasionally cause embarrassments. In the main, the normal observer of this kind causes greater loss of time than the color-blind. It is astonishing to see with what rapidity the color-blind betray their defect. At least, it is found, in the majority of the cases examined by us, that the first skein of wool selected from the pile by the color-blind in the first test was one of the "colors of confusion."

B. *Intervention during a restricted choice.*—Those who evince too great slowness also require the interferences of the examiner in another manner. We can lay aside here those cases in which at the sight of the complex colors of the heap of wool, the examined finds it difficult to select a skein resembling the sample in a collection where all the particular colors seem to differ from each other, and in consequence declares immediately that he can find none resembling the specimen. It is replied that an absolute resemblance is not demanded, and that no one asks impossibilities, that time is limited, many are waiting, etc. But there are people who from natural slowness, from being unaccustomed to such business, from fear of making mistakes, and especially if previously examined and suspected of color-blindness, or from many other motives, proceed with the greatest caution; they do not even wish to touch the wool, or they search, select, and replace with the greatest care all the possible skeins without finding one corresponding with the sample, or that they wish to place beside it. Here then are two cases: on one hand, too much action with the fingers, without result; on the other, too little effort. The examiner is forced to interfere in both cases.

(*a*) At the time of a too great manual action without corresponding practical result, the examiner must be careful that the eye and hand act simultaneously for the accomplishment of the desired end.

Some people forget that the hands should be subservient to the eye in this trial, and not act independently. Thus they are often seen to fix their eyes on one side while their hands are engaged on the other. This should be corrected so as to save time and avoid further labor. When, from the manual activity of the one examined, or by the unobserved aid of the examiner, all the correct skeins or only a portion are found in the pile, it is wise to stop and invite the former to cross his hands behind his back, to step back a pace, and quietly consider all the skeins, and, as soon as his eye has met one of those for which he is looking, to extend his hand and take it. The best plan is to advise him to look first at the sample and then at the pile, and to repeat this maneuver until his eyes find what he is looking for.

This stratagem generally succeeds when nervousness from over-anxiety causes his hands to tremble. But it is not always easy to induce him to keep his hands behind his back until the moment for taking the skein in question.

(*b*) In cases of great caution, the trial is hastened, if the examiner

come to the assistance of the other by holding above the pile one skein after the other, and requesting him to say whether it resembles the color of the sample or not. It will be advisable first to select the skeins that a color-blind person would approve. If he is so, he will approve of the selection, and the question is settled. If not, he rejects them, not without a characteristic smile, or with an expression of wounded dignity. This also enlightens us as to his chromatic sense. But even the color-blind may in such a case refuse what is presented, especially if his caution is premeditated, and he suspects that a snare is intended. It is found quite frequently that he rejects the correct shades likewise presented with the others. This is not the case when one, having a normal chromatic sense, is slow and deliberative when subjected to the test under this form. He has an eye alive to the correct colors.

One process, in cases of this last kind, is to select false samples which are placed quite near the correct one, by the side, above or below, to attract the attention of the examined from the right side. It is necessary so to proceed that the true sample be displaced when the others are drawn out, so that the person examined may see it move. It does not, however, always happen to catch his eye. The best means is then to make him examine the whole, with his hands behind his back, and invite him to freely make his choice. But, whatever the process, it is necessary, in every case where one has been assisted in selecting a certain number of skeins which he has found analogous to the sample color, to make a rule not to conclude the trial without examining into the effect of the aid accorded. It is necessary to hold in the hand the approved package, and ask if he is satisfied or if he would desire any change. If he approve the choice, the diagnosis is established. The same course must be pursued with the defective chromatic sense, that the trial may be made with or without assistance. To be thorough, the name given by the color-blind to the colors in question may be likewise asked.

In cases where any one suspected of color-blindness has remained some time to see the trial of others, and where, as often happens, he has remarked the samples belonging to a required green shade, he may of course profit by it in his own trial. But this can be prevented by furtively concealing one or two of these samples. If he seem to be disposed to confound green and gray, it will be very easy to entrap him. If we do not succeed, even when assisting him, in entrapping him in this snare, the hidden samples may be put back into their places, to be convinced that the trial is correct.

From the above, it is seen that many artifices may be necessary in our examination. It may be regarded as an advantage of our method that it has at command a great variety of resources. We have by no means mentioned all; and yet many who have only read this description will probably reproach us with having devoted ourselves too much to details which seem to them puerile. But we believe that those who have examined the chromatic sense of a great number of persons, and acquired thereby considerable experience, will think differently.

5.—APPRECIATION OF THE CAPACITY OF EXAMINEES.

The method of scrutiny here described is able to detect, as we have seen, not only complete or incomplete color-blindness, but a feeble chromatic sense. Moreover, it has been proved that there is a perfect gradation from complete color-blindness on the one side to the normal chromatic perception on the other. The question then naturally arises, from our practical point of view, whether it is possible to draw a dividing line between the kinds and degrees of defective color-vision which would except those who could not cause any inconvenience to the railway service, and, in case of an affirmative answer, where such limit is to be found.

It must first be remembered that in the existing state of things, these questions neither can nor ought to be settled in the same manner in every case, since the examination is intended for individuals of two different classes: 1st, the aspirants for railway employment; and, 2d, the employés, or those already in service.

A. *Aspirants.*—We must bear in mind that in Sweden, according to the regulation in force there for the management of state railways (followed also, as far as we know, on the private lines), it is required that, in order to be admitted, each applicant "prove by a certificate from a physician that he is exempt from any kind of infirmity, disease, or defect of conformation that could be prejudicial to the exercise of his functions," and also, that among these defects of conformation, in connection with signals, are reckoned the defects of the chromatic sense, to which the managers have especially directed the attention of the physicians attached to the lines.

According to the principles we have stated, the greatest severity should be observed in this case, or, in other terms, the least defect in the sense of colors should be a sufficient ground for rejection.

B. *Persons already in service.*—We must here ask ourselves if there is no necessity to modify the limit we have just traced, in order to carry out the principle we stated before, namely, that it is necessary to adopt less severe rules to eliminate from the service those who are already employed. We here encounter great difficulties, and it will be seen that it is not possible to settle the question summarily, that is, that a well-defined limit cannot be traced. In such cases, the physician should always, when he discovers a defect in the chromatic sense, give a certificate which should indicate its nature. These indications include, as we have already said, the diagnoses: *complete red-blindness, complete green-blindness, incomplete color-blindness, or a feeble chromatic sense.*

We are convinced that every case of complete color-blindness of both kinds, as well as every case of incomplete of the higher degrees, should be immediately dismissed. But as regards those who may be retained, it is clear that the first question concerns those who, at the time of the trial, were regarded in the diagnosis only as having a feeble chromatic sense, and then those who in the first test merely confound gray with

the sample color. But we do not venture to lay this down as a principle, for, if it should be proved that these individuals can generally distinguish the light of colored lanterns with sufficient accuracy, this does not prove that it is so in every case, and especially not at every distance required in the service. This is why we know nothing better to advise than to refer all such cases to competent specialists, as long as the transition period of which we have spoken lasts.

In the examination of doubtful cases submitted to my judgment, I determined according to several of the methods mentioned in one of the preceding chapters. In general, these persons were all subjected to a trial according to the methods of Seebeck and of Maxwell, and an examination by means of the visual perimeter and of colored shadows, as well as the lanterns of my invention and colored glasses. These last means have capacity especially in view, and they are very suitable for the object, when it is desired to investigate those who have been already discovered, by my method of Berlin wool, as having a defective chromatic sense.

The light of colored lanterns and illuminated surfaces generally, conveniently arranged and methodically used, may serve especially in such cases to enlighten us as to the faculty of the person examined for appreciating colored signals. Our experiences of this kind have shown us that the majority of color-blind railway employés, however much practice they have had, are utterly incapable of recognizing and distinguishing the regulation colors of lanterns, especially when they are employed in the shades which are not most commonly in use in the service. This applies not only to the completely red and green blind, but also to the incompletely blind. These last require the most circumstantial investigation, and it is not to be assumed that the lower degrees can stand the trial; they may often, it is true, distinguish the signal-lights at a short distance with sufficient accuracy, but they do not succeed at a comparatively greater distance. As the places where the trials are usually made do not command such distances as railways for observing signals, signal-lights cannot of course be used for these trials. They are replaced by small illuminated surfaces, which, seen from a suitable distance, produce exactly the same effect as lanterns at a great distance. Such surfaces are made by placing a screen with a suitable opening covered with a colored glass before the flame of a lamp. This is enough to show how to dispose of the case in question.

6.—EFFORTS TO CONCEAL OR TO FEIGN COLOR-BLINDNESS.

We have announced that none of the kinds of color-blindness we have in view in this work could escape discovery by our method. But this, of course, assumes that the subject does his best in the trial and acts in good faith. If it happen that one persists either in concealing a conscious color-blindness or for some other motive, in not giving the least information by act or word it is evident that the examination must fail from this

simple reason, and that it is impossible to draw any positive conclusion with regard to his chromatic sense. The examiner may in such a case mention unconditionally in the certificate that the one examined refused to submit to the usual examination.

It is not difficult to say how it is necessary to act with regard to such persons. It should, in fact, be to the interest of each one possessing normal sight, desirous of entering the service of railways, etc., to endeavor to be competent in every respect, and consequently to give manifest proof of his sense of colors. The color-blind alone have any interest in concealing their defect; therefore he endeavors to escape the trial. Every candidate who will try to avoid the prescribed trial must therefore be considered and treated as color-blind. Such obstinacy on the part of an employé must be considered and treated as an infraction of the regulations.

But cases may arise also in which those possessing normal sight will feign color-blindness, and act as if they were so affected. This may occur when some one wishes to receive a pension before the time, or else to escape punishment consequent upon an unexpected accident. These are just the very cases that put the method and perspicacity of the examiner to the test. The examination then assumes the character of a kind of criminal inquest, where the judge and the accused must give all the attention of which they are capable to their reciprocal acts and expressions, to try to entrap each other. The one examined tries to prove that he is color-blind, while the examiner endeavors to prove that he has normal sight. The prospect of coming off victorious in so singular a contest rests, in the last resort, with him who best understands the nature of color-blindness, and has most experience in the manner in which the color-blind act. To enable the pretender to deceive the examiner, it is absolutely necessary that he surpass the latter in knowledge of color-blindness. There is in this an element of success to the examiner, as it would be extremely rare to find a railway employé or sailor who would, under the circumstances mentioned, be subjected to an examination by a person inferior to himself in knowledge. It is clear, in fact, that an examination so difficult, so minute, and involving so much responsibility, should be confided to the most competent person possible. But it is, on the other hand, very improbable that a case should occur where it would be necessary that a learned and experienced specialist would have to submit to an examination.

In the first place, examinations of this kind must rarely occur, and when they do, it must be at least in the most difficult cases, that is to say, after an accident—under circumstances where the one examined has not had much time to study his part. It will generally be seen then that he has not a profound knowledge of the nature of color-blindness, but imagines it to be a difficulty or incapacity to distinguish signal-colors or colors in general. He will, therefore, be governed by this idea, and, either he will perfectly distinguish every other color so as to mistake only the signal-colors, or else he will believe he must confound no matter what

color. But, as we have seen, each kind of color-blindness follows laws as fixed as the normal sense. Such a stratagem will not fail to violate them, and the individual will be caught in the very act.

But there is absolutely nothing which opposes the supposition that this individual may have a certain knowledge of the nature of color-blindness, or, at least, that he may have an idea of its regularity with regard to the confusion of colors. He may have studied the proofs we have cited, and, owing to the exercise and observation of the color-blind, he will know how to perform them in a manner suitable to the object in view. The examiner has always, however, the choice of other sample colors, and the Berlin wool method affords a large choice. If that does not suffice, and the individual has learned from the truly color-blind to classify the whole collection of wool according to their chromatic sense, that is to say, that he can stand the trial according to Seebeck's method, and if he is so thorough in his part that there is no means of making him depart from it by abrupt or contradictory questions, the examiner may employ for the examination a number of other known methods, but probably unknown to our individual. It must not be forgotten here that it is generally easier to discover faults committed by others than to avoid being guilty of them one's self, and one must be profoundly familiar with his borrowed part not to be guilty of inconsistencies. With regard to feigning a certain kind of color-blindness, we know by our experience with regard to this, that it is a very difficult thing, and scarcely ever succeeds before an attentive and experienced examiner. All these circumstances are advantageous for the examiner, but his superiority is not limited to this. For if it should happen—an extremely improbable thing—that a pretender were familiar with all the known tests and methods, and besides had not less practice than talent in executing them as accurately as the color-blind, the examiner has, nevertheless, the power of inventing, owing to his special knowledge, new tests, and of varying those already known.

Besides the precaution, which must not be neglected, of conducting the examination in the presence of expert and competent persons, there is an especial means, which, while being certain of preventing all fraudulent attempts, judges the accused in the usual manner, that is, by the testimony of two persons. These two witnesses should be two color-blind of the same kind as that feigned by the examined. If these two individuals are first subjected separately and independently of each other and the *pseudo*-color-blind, to the same trial as he, let the results be noted down carefully, and then the whole three together, and it will then soon be seen how the case stands with one individual. The two color-blind will in this manner give the necessary testimony without resting upon the discretion of the examiner. This manner of proceeding must, however, be employed with caution and discrimination, as the conformity between two color-blind of the same class is not absolutely perfect in every respect. The result must, therefore, always be made to harmonize by the explanation of the examiner.

COLOR BLINDNESS.*

By Joseph Henry.

[From the Princeton Review, for July, 1845.]

It is an interesting fact in reference to the dependence of one class, at least of our knowledge, on sensation, that many persons are born with defective vision and yet remain for years of their lives without being conscious of the deficiency. We know a gentleman who had probably been always near sighted, but who did not discover the peculiarity of his vision until the age of twenty-five, when it was accidentally made known by looking at a distant object through a concave lens. Many persons whose eyes are sound and capable of exercising the most delicate functions, are permanently unable to distinguish certain colors. And the number of such persons is much more considerable than we would be led to imagine from the little attention this defect of vision has excited. It is often unknown to the individual himself, and indeed only becomes revealed by comparing his powers of discriminating different colours with those of other persons. The eye also under some circumstances may lose its sensibility for particular colors, or be thrown into such an unusual state as to present all objects to the mind under the appearance of a false color. Thus if a person looks fixedly for a time at a bright red object and then turns his eye to a white wall, he will perceive a green image of the red object depicted on the white surface. A lady of our acquaintance was once thrown into an alarming but laughable paroxysm of terror by an effect of this kind. She had been for some hours attentively sewing on a bright crimson dress, when her attention was directed towards her child, who, in its sport, had thrown itself on the carpet; its face appeared of the most ghastly hue, and the affrighted mother screamed in agony, that her child was in convulsions—the other inmates of the house hastened to her assistance, but they were surprised to find the little one smiling in perfect health. The sanity of the mother became the natural object of solicitude, until the effect was properly referred to the impression made on her eye by the crimson cloth.

Phenomena of this kind are known by the name of accidental colors; they have long attracted the attention of the natural philosopher, but the explanation of them is still involved in considerable uncertainty. The hypothesis which has been most generally adopted is that the eye by long attention to a particular color, becomes fatigued with this and

* 1. Observations on colour blindness, or insensibility to the impression of certain colours. By Sir David Brewster, K. H., &c. Philosophical Magazine.

2. Memoir on Daltonism, (or colour blindness.) By M. Elie Wartmann, Professor of Natural Philosophy in the Academy of Lausanne, &c. Scientific Memoirs.

is incapable after a time, of distinctly perceiving it; while it retains its full power of perception in reference to a fresh color. The consequence of this is that when the eye is directed to a white surface, after having attentively regarded a red object, green must appear; because white may be considered as a compound of red and green, and when the perception of the red is destroyed, the green must become visible. This explanation, however well it may apply to some of the phenomena, is not sufficient for the whole. Accidental colors can be perceived in the eye itself in perfect darkness. This is shown by steadily regarding for a short time a brilliant lamp, and then covering the eyes with the hands so as to exclude all external light, a luminous spot will be perceived which passes in succession through all the colors of the rainbow.

Of the real cause of these appearances we are as yet almost entirely ignorant. Professor Plateau, of Ghent, has indeed referred them all to a few simple principles, but these appear to us rather expressions of the law of succession of the phenomena, than physical explanations of them. We do not however at this time intend to dwell on this class of phenomena, but to give a succinct account of those peculiarities of vision, in which abnormal perceptions of color are permanent, and which are fully treated of in the memoirs, the titles of which stand at the head of this article.

The peculiarity of vision called *color-blindness*, and sometimes *Daltonism*, may generally be referred to two classes. 1. Those in which all impression of color, except white and black, are wanting. 2. Those in which the individual can perceive certain simple colors, but is not able properly to distinguish between them. There are persons, strange as it may appear, in whom the sense of primary color is entirely deficient, and who, in place of red, yellow and blue, see nothing but different degrees of white and black. Professor Wartmann gives a number of cases of this kind. The most ancient of those he finds described, is that by Dr. Tuberville, in 1684, of a woman, of about 32 years of age, who came to consult the Dr. about her sight, which, though excellent in other respects, gave her no impression in reference to color, except white and black. Spurzheim mentions a family, all the members of which could only distinguish different shades of white and black An account is given by Mr. Huddart of a shoemaker, in Cumberland, who could distinguish in different colors only a greater or less intensity of light, calling all bright tints white and all dull ones black. His peculiarity of vision was unknown to him until one day, while a boy, playing in the street, he found a stocking, and for the first time, was struck with the fact that it was called by his companions red, whereas to his mind it was capable of no farther description than that designated by the word stocking; he was thus led to conclude that there was something else besides the form and position in the leaves and fruit of a cherry tree, perceived by his playmates but not seen by himself. Two of his brothers had the same imperfection, while two other brothers, his sisters, and other relatives, had the usual condition of vision.

Of the other class, the cases are much more numerous; we shall, however, give only a few examples. Mr. Harvey, of Plymouth, mentions a

tailor who could see in the rainbow but two tints, namely, yellow and bright blue. Black appeared to him in general, green, sometimes crimson—light blue appeared like dark blue, crimson, or black—green was confounded with black and brown—carmine, red, lake, and crimson with blue.

But the most interesting case of this kind, is that of the celebrated chemical philosopher, Dr. Dalton, of England. He published an account of his own case and that of several others, in the Transactions of the Manchester Society, in 1794. Of the seven colors of the rainbow, he could distinguish but two, yellow and blue; or at most, three, yellow, blue, and purple. He saw no difference between red and green; so that he thought the color of a laurel leaf the same as that of a stick of red sealing-wax. A story is told of his having, on one occasion, appeared at the quaker meeting, of which he was a member, in the usual drab coat and small-clothes of the sect, with a pair of flaming red-colored stockings to match. Whatever may be the truth in reference to this story, we have the assertion of Professor Whewell, that when Dr. Dalton was asked with what he would compare the scarlet gown with which he had been invested by the university, he pointed to the trees, and declared that he perceived no difference between the color of his robe and that of their foliage. Dr. Dalton found nearly twenty persons possessed of the same peculiarity of vision as himself; and among the number, the celebrated metaphysician, Dugald Stewart, who could not distinguish a crimson fruit, like the Siberian crab, from the leaves of the tree on which it grew, otherwise than by the difference in its form.

On account of the prominence which Mr. Dalton's publication gave this defect of vision, the continental philosophers gave it the name of *Daltonism*. To this name, however, several British writers have strongly objected. If this system of names were once allowed, say they, there is no telling where it would stop, the names of celebrated men would be connected, not with their superior gifts or achievements, but with the personal defects which distinguish them from their more favoured but less meritorious cotemporaries. Professor Whewell proposed the term *Idiopts*, signifying peculiarity of vision; but to this name Sir David Brewster properly objected, that the important consonant *p* would be very apt to be omitted in ordinary pronunciation, and so the last state of the Idiopt would be worse than the first. The name *color-blindness*, suggested by Sir David, although not in all cases free from objection, is perhaps better than any we have seen proposed.

It has already been stated that the number of persons affected with color-blindness, is much more considerable than is generally imagined They are often themselves ignorant of their imperfection of vision, particularly when it is restricted to the want of power to discriminate between colors nearly related to each other. Professor Seebeck found five cases among the forty boys who composed the two upper classes of a gymnasium of Berlin. Professor Prevost, of Geneva, stated that they amounted to one in twenty; and Professor Wartmann does not think this estimate much exaggerated.

Observations on this peculiarity of vision have as yet been confined,

so far as we know, to Europe, with the exception of two cases described by Dr. Hays, of Philadelphia, in the Proceedings of the American Philosophical Society. It has also as yet been found only among the white race, although sufficient observations have not been made to render it probable that it is confined to this variety of the human family. The question has been asked, whether there is any external sign by which to detect, with simple inspection of the visual organ, a case of color-blindness. Professor Wartmann remarks, that he would not venture to give an answer to this question in all cases in the negative. I have observed, says he, in the case of *Daltonians* whose eyes are brown, of the color which the English call hazel, a golden lustre of a peculiar tint, when the eye was viewed under an incidence of some obliquity.

Color-blindness is found much more common among men than women. Out of one hundred and fifty registered cases, there are but six of females, and one of these is doubtful. It has been conjectured that needle-work on a variety of colored articles, might be the means of counteracting the tendency to this defect, as well as to produce a delicacy of discrimination of different shades of color not possessed by those otherwise employed. But, in answer to this, it has been remarked, that in the case of Daltonians engaged in painting, there has been found but little, if any improvement of condition of the vision; and the very employment of the females on works which require a constant comparison of color, would daily reveal cases of blindness of this kind, did it frequently exist in the female sex. This peculiarity of vision is principally congenital. Professor W. has found but two exceptions. In one of these, colors were perceived in the usual manner, until at the ninth year, when at that time the boy received a violent blow on the head, which fractured the skull, and rendered surgical operations necessary. The fact, however, that three of the brothers of this individual were affected with the same kind of vision, renders it probable that he was constitutionally predisposed to this peculiarity.

With regard to hereditary predisposition there are some persons in whom this defect of vision occurs, whose relatives have never been known to be affected with it; others appear to have inherited it from their fathers through several generations, both on the maternal and paternal side. The boy before mentioned, as becoming blind at the age of nine years, was the eldest of eleven children, seven males and four females; these were singularly divided into two sets, one of which consisted of individuals with blond hair, and all the males with defective vision; the other, of those with red hair and ordinary power of vision.

Dr. Seebeck, as well as Professor Wartmann, has made a series of experiments to determine whether a person of this peculiarity of vision possesses the power of perceiving differences in colors which appear identical to us. The result of the investigations of both these philosophers was that he does not. Another problem has also been solved by the last-mentioned gentleman, in reference to the difference between a person with this defective vision, and one of ordinary conditioned sight, in

the perception of complementary colors. He found that colors which we regard as complementary, or such as when mingled together produce white, do not appear as such to those affected with abnormal vision. They are not however insensible to accidental colors, but the feeling which results from the fatigue of attempting to produce these appears to be more painful in them than in us.

Various hypotheses have been advanced by different persons for the explanation of color-blindness. Mr. Dalton supposed that his peculiarity of vision, as well as that of those whom he had examined, depended on the fact that the vitreous or principal humour of the eye, in these cases, instead of being colorless and transparent was tinged with a blue. After his death, in obedience to his own instruction, his eyes were examined by his medical attendant, Mr. Ransome, but the vitreous humour was not found to exhibit any tinge of blue; on the contrary, it was of a pale yellow color. Objects viewed through it were not changed in color as they should have been had the hypothesis been true. Indeed, were the supposition correct, the same effect should be produced by blue spectacles, which is known not to be the case.

Stewart, Herschel and others are of the opinion that this malady of vision is attributable to a defect in the *sensorium* itself, which renders it incapable of appreciating the differences between the rays on which the sensation of color depends. Sir David Brewster conceives that the eye, in the case of color-blindness, is insensible to the colors at one end of the spectrum, just as the ear of certain persons is insensible to sounds at one extremity of the scale of musical notes, while it is perfectly sensible to all other sounds. He knows nothing about the *sensorium* or its connection with, or mode of operation upon, the nerves of sensation; and from the analogy of sight and hearing, he has no hesitation in predicting that there may be found persons whose color-blindness is confined to one eye, or at least is greater in one eye than in the other. Nor is this, says he, wholly a conjecture from analogy, for my own right eye, though not a better one than the left, which has no defect whatever, is more sensible to red light than the left eye. The case is precisely analogous with respect to his ears, for certain sounds; and no person, it is presumed, will maintain that there is a sensorium for each ear and each eye.

Whatever may be the cause of the inferiority, there exists a very easy means of rectifying it to a certain extent. This method, first used by Dr. Seebeck, consists in viewing colored objects through colored media. Suppose the medium to be a piece of red glass; the impression of a red body and of a green one on the eye of a person like Dr. Dalton, would be different, although with the naked eye they would be the same. The red glass would intercept much more of the light of the green object than of the red one, and hence the two would be readily distinguishable by a difference in the intensity of the illumination of the two objects. Nothing can equal the surprise, says Professor Wartmann, of a *Daltonian* when the errors which he commits every day in the appreciation of colors are thus disclosed to him.

REPORT ON THE TRANSACTIONS OF THE GENEVA SOCIETY OF PHYSICS AND NATURAL HISTORY, FROM JUNE, 1874, TO JUNE, 1875.

By E. Plantamour, *President.*

Translated for the Smithsonian Institution by M. L. Duncan.

Gentlemen: I shall conform to the established usage of treating, in the first part of this report, questions relating to the membership and administration of our society, and of giving, in the second part, a succinct statement of its scientific labors.

Our society has met this year with a very great loss in the death, at Geneva, March 7, 1875, of Dr. Chossat; if medical science has lost in him one of its most distinguished representatives, we have also to mourn a colleague who felt the liveliest interest in the labors of the society, in which, from 1830, he took an active part, and of which he became president in 1863, and for many years punctually attended its meetings. The great reputation of Chossat's works extended far beyond the confines of Geneva, and exercised a remarkable influence on the science to which he had devoted himself; he was, so to speak, better known abroad than in his own country, where he was, without doubt, fully appreciated by his associates of the Society of Medicine and Physics, but where, however, the influence and consideration he enjoyed among his countrymen had not reached the level of his reputation abroad. Being myself unacquainted with the science cultivated by Dr. Chossat, it would be very difficult, if not impossible, for me to give an even imperfect account of his labors and life, without having recourse to the assistance of a more competent person; it is to the kindness of our colleague, Dr. J. L. Prévost, that I am indebted for the following notice:

Dr. Charles Étienne Jacques Chossat, born at Carouge, April 30, 1796, was descended from a French family originally from the environs of Valence, who had taken refuge in Geneva, in consequence of the religious persecutions so cruelly waged in the Cévennes in the eighteenth century. Chossat first studied with Pestalozzi, and on leaving the Institut d'Yverdon, continued his studies at the Academy of Geneva. While still young he evinced a very decided taste for the natural sciences and medicine, which latter he intended to embrace. In 1813, Chossat, then seventeen years of age, would have been enrolled in the Guard of Honor (*gardes d'honneur*), if his father had not entered him as a student of theology, either at Geneva or Montauban. This decision was entirely

antagonistic to the scientific tastes of Chossat, who, while attending the lecture-room of theology to please his parents, was secretly studying anatomy, under the auspices and direction of Dr. Coindet, then at the head of the Hospital of Geneva, who gave him access to his library and to the hospital. In 1815, after having obtained the degree of bachelor of sciences, Chossat left for Paris, where he zealously devoted himself to the medical and physiological sciences, under the auspices of Magendie, his instructor, and at a later date his friend. In addition to his medical studies, he assiduously attended courses of lectures on physics, by Gay-Lussac and Biot; on chemistry, by Thénard; on comparative anatomy, by Cuvier; on astronomy, at the observatory, by Arago; and on the differential and integral calculus and applied mechanics, by Lacroix and Poisson. These numerous studies did not prevent him from undertaking original researches, for, in 1817, he published his first memoir, "*On the relation of the sine of refraction to the refracting media of the eye*"; and the year following a second memoir, "*On the curvature of the media of the eye.*"

United by ties of friendship with one of his former school-companions, Dr. J. L. Prévost, from Edinburgh, Chossat made with him, in the course of the same year (1818), a great number of experimental researches on death by cold and on the mechanism of refrigeration—experiments briefly stated in his thesis for the degree of doctor, which was the object of his labors for the year 1819.

In 1820 he presented to the Academy of Sciences a memoir "*On the influence of the nervous system on animal heat.*" In this work, which he made the subject of his thesis, and which confirmed the former researches of Brodie and Legallois, he attributed to the ganglionic nervous system the power of directly developing heat, independently of the combustion exercised by respiration. His conclusions are not all now admitted, but the facts observed were exact, and only their interpretation has varied since then.

After having received the degree of doctor in 1820, Chossat passed several months in England, where his scientific researches, already known, caused him to be kindly welcomed by Brodie, Astley Cooper, Abernethy, Humphrey Davy, et al. He visited the faculties of Edinburgh and Dublin, and then returned to Geneva, whence he soon set out as private physician to an Austrian countess, with whom he traveled for several years in Germany, France, and Switzerland, and in the south. During these travels he made prolonged sojourns in the most important cities, passing all his winters in Italy, which he learned to know throughly. Meanwhile, however, he did not abandon study and experiment; it is in fact to this period that we trace several of his works. It was during a long stay at Pisa, in 1824, that he completed a memoir "*On the analysis of the urinary functions*," in which he sought experimentally the circumstances in man influencing the secretion and composition of urine. This very important memoir, which contains new and numerous observations, won the prize for experimental physiology at the Academy of

Sciences in 1825, and was inserted the same year in Magendie's Journal of Physiology. It was at the same time, during his winter residence in Rome, Florence, and Naples, that he began his experimental researches on inanition, a work to which he consecrated several years of diligent labor.

In 1828, Chossat, leaving Italy, returned to establish himself permanently in Geneva, where he was married; from that period he divided his time between the duties of his practice and his scientific labors. Resuming his studies, and pursuing them with indefatigable perseverance, he presented in 1838, to the Academy of Sciences, his researches "*On inanition*"—a work remarkable from the importance of the results obtained and the influence it soon exercised on the dietetics of acute diseases. A short time after, this memoir gained the prize for experimental physiology, which won for its author, from the year 1846, the title of corresponding member of the Academy of Medicine of Paris, and in 1865 the cross of the Legion of Honor. In this work, Chossat collected and grouped the results of his researches, some of which had already been stated in several notes addressed to the Academy of Sciences. He studied the influence of the deprivation of aliment in general, and showed that an animal dies when it has lost, on an average, 0.4 of its initial weight. With warm-blooded animals, the integral loss seems to be independent of the class to which the subject under experiment belongs, as well as of the normal weight of its species. This average figure of 0.4 for the adult animal varies, however, in its already quite extended limits, according to the strength, age, and obesity of the subject. With a very fat animal, the loss might be increased to 0.5, while with the young it can scarcely exceed 0.2. The author also very carefully studied the diminution of temperature caused by inanition. These data are of essential importance in the treatment of diseases, by showing the injurious influence of too restricted a diet.

Chossat then studied the influence of the deprivation of nitrogenous food by subjecting animals to an exclusively sugar diet, as well as the influence on the skeleton of mineral inanition, or of the deprivation of saline substances.

It is impossible to give here even an incomplete summary of an authoritative work, justly become classic, and one of the chief sources of Chossat's fame. In this work, as in all his other researches, Chossat distinguishes himself by a remarkable scientific conscientiousness, a minute exactness in his experiments, and a careful and truthful analysis of facts. The author excludes every doubtful fact; and it is only after convincing himself of his accuracy by new researches that he draws conclusions. "In brief," said Chossat, and it is in this way he ends his memoir, "*inanitiation** is a cause of death, which marches silently and

* See on the subject of *inanitiation* the following note, p. 9 of the memoir: "I find myself regretfully obliged to invent a new term, though according to grammatical analogy, to express the gradual passage of the body to a state which is only really inanition at its close. Inanition is, correctly speaking, but the end of inanitiation."

abreast with every disease in which the alimentation is not in a normal condition. It reaches its natural limit sometimes sooner and sometimes later than the disease it silently accompanies, and may then become the principal disease in instances where it was at first but symptomatic. It might be recognized by the degree of the destruction of the muscular fibers, and its actual importance measured each moment by the relative weight of the body."

Constantly occupied with the task of verifying and completing his researches, Chossat undertook the study of osteomalacy by saline inanitiation, when in 1842 he was invited to constitute one of the board of public instruction. Carrying into these new functions all the zeal and perseverance which characterized him, he was obliged to abandon his original scientific researches. Appointed in 1845 member of a commission charged by the department of public instruction to organize a system of instruction for the industrial and commercial classes of the canton of Geneva, he drew up, as reporter, a detailed memoir, the conclusions of which, logically deduced, were applied at a later date.

In 1848, the board of public instruction was dissolved, and Chossat retired again into private life, but the time he was obliged to devote to a large practice, and the fatigue attending it, forced him reluctantly to renounce his original labors, which he felt, he said, that he had no longer the time and strength to continue in a regular manner. Although he gave up writing, he still continued to occupy himself with the most varied scientific and literary subjects. The taste for reading, which he indulged, finally became a veritable passion, and even in the last years of his life he kept himself informed of all the principal scientific discoveries, not, however, neglecting for this the ancient writers, especially Plato, upon whom he loved to meditate.

Attacked by an organic disease of the stomach, which made rapid progress in a body worn out by intellectual and physical labors, Chossat awaited his end with resignation, preserving his faculties to the last moment sufficiently to be able to announce, himself, to his family, some hours before dying, the precise moment of his death. This distinguished scientist died March 7, 1875, in the seventy-ninth year of his age.

The society had to award this year the prize founded by A. P. De Candolle. The prize was adjudged to Professor Radlhofer, of Munich, for a monograph on the Sapindaceous family.

The second part of volume xxiii of the memoirs of our society appeared during the course of last autumn; the first part of volume xxiv is now in press, and includes the second part of the memoir of Messrs. de Loriol and Pellat.

The Geological Society of France having communicated its desire to meet in Geneva in 1875, to hold there a portion of its annual session, the society appointed a committee, composed of MM. Alphonse and

Ernest Favre, de Loriol, de Saussure, and Soret, to arrange this matter. This committee, which had the power of adding new members, was commissioned to take measures for the reception of the Geological Society during its stay in Geneva.

RÉSUMÉ OF SCIENTIFIC WORK.

1. *Physical sciences.*—Professor Colladon read before us a memoir inserted in No. 212 of the *Archives des Sciences Physiques et Naturelles* (Archives of the Physical and Natural Sciences), October, 1874, on the vestiges of a former bed of the Arve, discovered by digging for the foundations of the new theater. The excavations made on this occasion, at the foot of the terraces of Treille and Tertasse, disclosed the presence of a bank of gravel and sand from 2.1 to 2.5 metres (7 to 8 feet) in depth, lying on a bed of clay whose upper surface is 0.85 metre (33 inches) below the mean level of the waters of the lake at the present time. The orientation of the stones and pebbles forming this bank indicates that it must have been deposited by a current flowing from the southeast toward the northwest, and the chemical and mineralogical composition of the sand is absolutely identical with that of the sand now drifted by the Arve, and proceeding from the rocks forming the chain of Mont Blanc. There can then be no doubt that at the era when this deposit was formed, the Arve emptied into the Rhone, very near its issue from the lake, and within the inclosure of the present city, whereas the confluence is now more than a kilometer (about a mile) down stream. The existence of this bank of gravel and sand, at different points of the plain of alluvium, comprised between the city and the present bed of the Arve, had already been established on several occasions; and it might therefore be concluded that the direction of the current of the lower portion of the Arve has gradually changed in the course of centuries, and that after flowing by the foot of the hill, on which the most ancient part of the city is built, the river empties into the Rhone at the foot of the hill on which the forest of Batie is found. The era to which the deposit of gravel mentioned by M. Colladon dates back does not appear to be very remote, not exceeding twenty or thirty centuries, as within the interior of these ancient strata, which have never been touched, are found fragments of bricks, and even pieces of wrought iron very much rusted. The fact that the upper surface of this deposit is about 1.5 metres (5 feet) above the mean level of the waters of the lake at this present time is mentioned by M. Colladon as proof that this level must have been sensibly higher by at least two metres (6½ feet) at the period of its formation.

Dr. F. Florel communicated a memoir, inserted in No. 205 of the *Archives*, January, 1875, on the configuration of the bottom of Lake Leman, in accordance with the four maps of the topographical atlas of Switzerland, published by the Federal Bureau of the Staff Office. These four maps, drawn on a scale of $\frac{1}{25000}$, according to the notes and sound-

ings taken by the engineer, M. Ph. Gosset, include the Swiss bank of the lake, from Saint Sulpice to Saint Saphorin, with the opposite bank and the intermediary basin, which attains at this place its greatest depth of 334 metres (1,000 feet) below the surface. The same number of the *Archives* contains a memoir of M. Ed. Pictet-Mallet, read before the society during its session of January 7, 1875, and relating to an analogous subject. M. Pictet-Mallet undertook the task of representing on a chart, projected on a scale of $\frac{1}{12500}$, and traced with contour-curves at equidistant levels of 5 metres, (16 feet) the configuration of the bottom of the lower part of Lake Leman; that is, the space comprised between Coppet, Hermance, and Geneva. The portion of this work nearest the city is not yet completed, but it contains a thorough discussion of the advantages and disadvantages of the different methods that may be followed in the operation of soundings, and quite singular details about the inequalities of bottom presented by the lake in the portion that has been explored.

M. Plantamour gave a summary of the observations relating to the variations of the level of the lake during the year 1874. By the indications of the limnimeter of the Jardin Anglais (English Garden), the mean annual level was within two millimetres, (one twelfth of an inch), the same as that deduced from the thirty-six preceding years, but with a greater annual variation than usual, say 1.69 metres (67 inches), instead of 1.44 metres (57 inches). From February to June, the level was below the mean; the absolute minimum occurred on the 10th and 11th of March, and was 9 centimetres (4 inches) below the mean annual minimum. *Per contra*, from July to October, the level was above the mean, and the absolute maximum exceeded by 16 centimetres (6 inches) the mean level of high stages of water. The gauges established at two other points of the canton of Geneva, at Sécheron and Genthod, and at three other points on the Vaudois shore, Ouchy, Vevey, and Chillon, the daily readings of which were transmitted by the engineer of the canton of Vaudois, (M. Gonin,) admitted of a comparison being made from day to day, and from month to month, of the level of the lake on the right shore along its entire length; the zeros of all the scales of the gauges having been made to correspond in the operations of running the level of Switzerland. By these observations it is ascertained that the inclination of the lake is almost insensible from its upper extremity to 1½ kilometres (1 mile) above the city of Geneva, the admitted level at Sécheron being during the entire year within a few millimetres the same as at Vevey and Chillon, and the chance depressions shown by the deviations among the heights observed on the same day from one extremity to the other being very small and limited to a few centimetres. From Sécheron to the limnimeter of the Jardin Anglais, the slope is very appreciable, as might have been expected from the existence of a very sensible current in the immediate vicinity of the city; moreover, the inclination varies with the season; it is very slight in winter, and at the opening of spring, at the

time of low water, and it is from 5 to 6 centimetres (2 inches) greater in summer at the time of high water. If the level of the water is sensibly the same during the whole year at Chillon, Vevey, and Sécheron, the observations taken at Ouchy show a level lower by 2 centimetres (1 inch), and at Genthod, on the contrary, higher by 2 centimetres, the difference remaining also sensibly constant during the whole year 1874. The observations taken in the three preceding years at Chillon, Vevey, and Ouchy confirm the constant depression of level at the latter place relatively to the other two. It would appear difficult to attribute this anomaly to errors in the agreement of the zeros of the different scales; yet new measures of verification will be taken to put the fact itself beyond all question.

M. Plantamour, in conjunction with Professor Hirsch, presented the results of the latest operations of léveling; these results are recorded in the fifth number of the Topography of Switzerland, published by the Federal Geodetic Commission.

Professor Thury presented a memoir on photometry, and on an astronomical photometer of his own invention; this memoir was inserted in No. 202 of the *Archives*, November, 1874. Professor Thury's photometer is constructed upon the system of the extinction of the light of a star, an extinction produced by the reduction of the aperture of the object-glass by the help of a diaphragm, or by the reflection of pencils of rays by a system of mirrors. The diaphragm in this apparatus consists of 16 thin rectangular plates, capable each of sliding in the direction of its length and in the direction of the center of the object-glass. By a very ingenious mechanism, the movement of these 16 plates is so co-ordinated that their small interior sides form a regular polygon, the diameter of which can vary from zero to the diameter of the object-glass. In order to prevent the inconveniences resulting from false disks, produced by too great a diminution of the aperture of the objective, a diminution which might be necessary to bring about the extinction of a brilliant star, Professor Thury has recourse to the interposition of one or two black mirrors perfectly plane, and receiving the incident ray at an angle of 45°. The extinction of the light can be produced either by the diminution alone of the aperture for a star of moderate brilliancy, or by the interposition of one or two mirrors, according to the brightness of the star, and not reducing the opening below 0.23 of the total aperture. In each of these three cases the position of the eye-glass is of course different.

Professor Thury also presented a memoir on the experiments he made in connection with Dr. Minnich, relative to a disengagement of electricity from the thermal waters of Baden (Aargau). These experiments, which appeared in No. 205 of the *Archives*, January, 1875, furnish the means of verifying the existence of a very decided electric current, which is revealed by the galvanometer, when by means of electrodes the water of the Limmat is placed in communication with the thermal spring, the direction of the deviation indicating that the mineral spring is electrified

negatively. Professor Thury intends resuming and continuing these experiments.

M. Soret read before the society a memoir, inserted in No. 199 of the *Archives*, under date of July, 1874, on polarization by diffusion of light. He described and discussed in his memoir the experiments that he made on the reflecting power of flames on the proper colors of bodies, and on the cause of the illumination of transparent bodies and the diffusion of light; experiments in which he studied a large number of crystalline substances, such as quartz, diamond, rock-salt, etc.

M. Soret also presented a memoir on the phenomena of diffraction produced by a circular grating, a paper inserted in April, 1875, in No. 208 of the *Archives*. He gives the name of circular grating to opaque screens pierced by a series of circular openings presenting the form of concentric rings. He further indicates the method he took for constructing such a grating, and for producing upon a glass plate of small dimensions a series of 196 concentric rings, alternately transparent and opaque, the central part being transparent in the positive grating and opaque in the negative grating; and the radii of the circles bounding these rings increasing proportionally to the square roots of the series of natural numbers. He has shown that a circular grating of this kind can perform the office of a non-achromatic object-glass; an inverted image is produced of a distant luminous object, and this image passes through the different colors of the spectrum, according to the distance of the grating.

M. R. Pictet communicated the results of his experiments made in Egypt on the propagation of the calorific rays of the sun through different substances, sand among others. He undertook to verify the idea expressed by M. Soret, that sand acts after the manner of a plate of glass; that is to say, it would be found diathermanous to luminous heat and athermanous to dark heat. M. Pictet found, in fact, in the action of temperature, more agreement of sand with glass than with other substances, such as wood or sheet-iron, even when the latter were painted the color of sand.

The same member explained to the society a new process for the manufacture, on a large scale, of sulphurous acid, which consists in pouring sulphuric acid, drop by drop, on sulphur, heated to from 300° to 350° C. (572°—662° F.), in a cast-iron retort. He stated some of the properties of the sulphurous acid prepared in this way, as well as those of the sulphite of water, obtained by the addition of water in a determined proportion.

M. E. Demole read a work, inserted in No. 204 of the *Archives*, December, 1874, on the question of molecular transpositions in the aromatic series. Taking up again the experiments of M. Lautemann on the products of the distillation of oxysalicylic acid, M. Demole reached the conclusion that the products obtained by the latter were due to the circumstance that the oxysalicylic acid employed was not pure, but contained

proto-catechic acid. With pure oxysalicylic acid, M. Demole obtained hydroquinine and a small quantity of pyrocatechine. The formation of these two dioxybenzols is a curious fact, the theoretical explanation of which is still rather obscure.

The same member communicated a memoir, published January, 1875, in No. 205 of the *Archives*, on the reaction of the bromide of ethylene on diluted alcohol, in presence of the acetic ethers of glycol. M. Demole made numerous experiments for the purpose of explaining the formation of the products due to this reaction, namely, of glycol, brombydrine, acetate of ethyl, and bromide of ethylene.

2. *Natural sciences.*—Prof. A. Favre submitted a communication on the altitude of the glaciers at the Glacial era, and the height that must be attributed to the summits of the Alps, if the slope of the glaciers were the same at that time as at the present day. Among the maps of the topographical atlas of Switzerland, executed by the Federal Bureau of the Staff Office, there are some referring to the Bernese Jura, in which are found represented, on the flanks of the Chasseral, erratic blocks of considerable bulk, at altitudes varying from 1,200 to 1,300 metres (about 4,000 feet). These blocks have drifted from the mountains which command the present glaciers of the Rhone, and are 260 kilometres (162 miles) distant from the Chasseral. By assuming that the glaciers of the glacial era had a slope equal to the minimum slope of the present glaciers, namely, from 2 per cent. to 1½ per cent., the result would be a difference of altitude of 5,200 and 3,900 metres, (17,000 and 13,000 feet) respectively, between the upper and lower part. From the altitude of the latter, which is 1,300 metres (4,000 feet), there would result 6,500 or 5,200 metres (20,000 or 17,000 feet), for that of the upper part, or a sum greatly exceeding the height of the Galenstock, one of the most elevated summits bordering on the glaciers of the Rhone, which rises to a height of 3,600 metres, (12,000 feet). We would thus have to admit that either the height of the Alps at the Glacial era greatly exceeded the present height, or that the slope of the glaciers was considerably less. This last hypothesis is quite admissible from the results of the recent explorations of the polar regions, especially those of Greenland, but nothing forbids the admission of the combined action of both causes.

Professor Favre also presented a memoir on the recession of the glacier of the Bossons of late years, and on the relation between the advance and retreat of glaciers and the atmospheric conditions, especially the summer temperature. In the last eight years, included between July, 1866, and June, 1874, the glaciers of the Bossons receded 212 metres, (696 feet), and at the latter date it was 682 metres (2,240 feet) in rear of the point it had reached in 1818, the epoch of its greatest development in this century. If within late years the retreat of the glaciers can be explained by the elevation of the mean temperature, especially in the summer months, their development at an anterior period can likewise be attributed

to the effect of a series of cold and wet years. The series of meteorological observations conducted at the foot of the Alps, in Switzerland, do not go far enough back to enable us to compare the year 1816 and those immediately preceding or following it with the mean temperatures deduced from a great number of years. M. Favre was only able to institute the comparison by the observations made at the observatory of Paris from the beginning of the century; these observations show for Paris a series of cold years from 1810 to 1818, in which the lowering of the temperature was more marked in the summer months, when the thawing of the ice especially takes place. If we cannot admit a complete parallelism between the course of the temperature at Paris and at the foot of the Alps, still the alternations of dry and hot years and cold and wet ones must afford a certain analogy, because they are due to general phenomena, embracing a considerable part of the surface of the globe.

M. Ernest Favre presented a summary of the work he is now publishing in the Memoirs of the Helvetic Society of Natural Sciences, on the geology of the central Caucasian chain; this work is the result of the exploration recently made of that region, and is accompanied by a geological chart and numerous cuts. M. Ernest Favre read a memoir on the geological structure of the southern part of the Crimea; among the other conclusions of this work, M. Favre expresses the idea that the Crimean chain is not, as was thought, a prolongation of the northern chain of the Caucasus; the prolongation of the latter to the northwest connects with the granitic zone, which reaches into Poland and into the east of Europe. The Crimea is left, by this prolongation, to the south, and seems rather to belong to the mountains of Turkey and Asia Minor.

The same member finally communicated the results of an exploration recently made by him, of a mountain of the Voirons, with the view of verifying the geological section of that mountain, given by his father in his work on the geology of Savoy. He was enabled by this new examination to confirm the perfect accuracy of the section as published.

Professor Renevier presented to the society geological tables, which are more especially intended for facilitating the teaching of geology and the study of the sedimentary rocks during the organic eras of the globe. These tables contain, under a synoptical form, all the data relating to the succession of the rocks, their geological age, their area, and their most characteristic fossils.

Professor de Candolle communicated the results of his experiments for studying the manner in which buds receive the impression of the heat that promotes their unfolding; he reaches the conclusion that the heat is collected as well by the wood that bears the bud as by the bud itself.

M. Duby read a memoir on some new, or but little known, mosses, drawn largly from the Delessert collection, and the description of which is illustrated by plates. He discovered among these mosses a new kind, altogether anomalous, to which he gave the name of *Hymenocleiston*.

M. de Saussure, in presenting to the society the third part of his studies of the *Orthoptera*, which is devoted to the family of the *Gryllidæ*, gives a few details of the musical organ with which the males of this family are endowed. The singing is produced by the intercrossing and very rapid friction of the two elytra against each other. He shows the series of transformations that the elytron undergoes in the male to render the production of a sound possible, whereas with the females the elytron remains in the normal state.

M. Fatio read a memoir on the different development of the pectoral fins in the two sexes among some fish of the genus *Cyprinus*, which live in the waters of our environs, especially among the minnows. With these fish, particularly in the rutting season, the swelling and development of some of the larger rays of the males have the effect of expelling and causing the disappearance of the smaller rays, so that their number is reduced to ten, and even to six only, while in the female the rays are always very slender and from fourteen to sixteen in number.

The same member communicated a memoir on a curious case of melanism, of nodose melanosis, which is sometimes observed in fish of the genus *Cyprinus*, and which is due to the presence of a small parasite which M. Humbert recognized as a helminth. These two memoirs were published in No. 205 of the *Archives*, of January, 1875.

Dr. Fol presented a summary of researches made by himself, on the development of the egg of the *Medusæ* and the Pteropodous Mollusks, during his stay at Messina; he studied particularly the mode of formation of the egg-shell of the latter.

The same member communicated the principal results of the investigations to which he had been devoting himself for some years, into the development of the nervous system and the sexual organs of the Mollusks. M. Fol studied in the embryos of Pteropods (which more particularly favor these researches), the mode of formation of the nervous system, as well as the organs of hearing and sight. Finally, M. Fol communicated the results of some observations made by him at Messina, upon the origin of the generative organs, male and female. These investigations led him to adopt the views of M. Ed. Van Beneden on this subject.

Dr. Prévost presented the results of some experiments he recently made on the physiological properties of the Jaborandi. The effects produced by an infusion of this plant are quite similar to those produced by the muscarine, consisting in a powerful salivation, and in a general way in an exaggerated secretion of all the glands except the kidneys. Atropine may be considered as antagonistic to this new substance, as well as to the muscarine; it can, in fact, be employed to arrest the salivation produced by the two other poisons.

Independently of these memoirs read before the society, a large number of different communications were made, and reports of discoveries

and labors abroad. In this way, Professor Gautier continued to keep the society informed of the progress in astronomy, and in the physics of the globe, by communications on various subjects, such as the preparations for the observation of the transit of Venus by the English expedition, from the Annual Report of the Royal Astronomer; observations made at the Roman College on magnetic variations and their relations with the maxima and minima of solar spots; appearance of the belts of Jupiter, from a memoir published in the *Monthly Notices;* a new theory of the aurora-borealis, from a memoir by M. Grönemann, inserted in the *Astronomische Nachrichten;* a memoir of M. Montigny on scintillation; the orbit of Coggia's comet and the phenomena presented by it during its apparition; the present state of our knowledge of the small planets; finally, the work of Père Rosa on the variableness of the solar diameter. The same member, while announcing to the society the deaths of the astronomers Argeländer and Mädler, gave a sketch of the character and works of these scientists.

M. Soret gave a description of a new thermometer invented by Negretti in London, for measuring the temperature of water at great depths, without having recourse to the index; the same apparatus, placed in communication with an electric current, which reversed it at a determined instant, might serve to record the temperature, without necessitating a direct reading at the same moment. M. Plantamour has sent for one of these instruments, with which he proposes to measure the temperature of the lake at different depths.

Professor Wartmann presented a *résumé* of M. Jamin's method for the study of magnetism, and of some of the results obtained. M. R. Pictet gave some details of the exceptionally great rise of the Nile in 1874. The same member described Boulanger's teleometer.

Professor Marignac gave an account of a work by Dr. Wagner on the antiseptic properties of salycilic acid.

M. E. Ador presented to the society a glass jar containing meat preserved for nearly two months by M. de Herzen's process; this meat was as fresh as on the first day, and had undergone no change.

Prof. A. Favre gave an account of a work by M. Zittel on the glacial terrain of the south of Bavaria.

M. E. Favre mentioned a work on comparative geology by M. Stanislas Meunier, and a work by M. Stoppani on the glacial terrains of the southern slopes of the Alps. The same member made a communication on some implements he had seen at Basle, at the residence of M. Rutimeyer, and which were found in the lignites of Wetzikou. These implements give evidence of the presence of men in Switzerland before the second Glacial period.

Professor Candolle, when presenting to the society his notice of M. Meisner, accompanied it with some details relative to the botanist of Basle. The same member gave a recapitulation of Mr. Asa Gray's work on the natural extinction of varieties of fruit-trees, and also the results

obtained from the restoration of the growth of trees to the Island of Ascension, from an article by Mr. Bell, inserted in the Gardener's Chronicle.

M. Micheli presented a branch of the genus *Ficus repens* bearing fruit, which is remarkable from an extraordinary transformation of the leaves. The same member gave some details of the flora of the central and northern country of the Argentine Republic, from collections made by M. Lorenz, and described by M. Griesebad.

M. Ph. Plantamour invited the members of the society, or those whom it might interest, to his residence, to see two plants of *Armophoptales Rivieri*, just ready to bloom.

M. A. Humbert pointed out a peculiar change in the lenses of the microscope, which he attributed to algæ attached to the glass, and produced by humidity. The same member described a work by M. Gerstaecker on the respiratory organs of certain insects, and of a memoir of M. Zeller on the development of the larvæ of intestinal worms.

Dr. Lombard made a communication relative to the accidents in the last ascension of the balloon, the *Zenith*. He dwelt upon the consequences of the diminution of the quantity of oxygen contained in a litre of air at a great height, and on the internal and external peripheric motions produced by a too rapid ascension.

Dr. Prévost presented a *résumé* of the researches recently made on apomorphine, and the effect produced by this substance on different animals. The same member summed up the most recent observations on the hypnotic action of hydrate of chloral, the use of which may be regarded as dangerous to man, but which is capable of rendering great service in experiments by vivisection of animals.

REPORT ON THE TRANSACTIONS OF THE GENEVA SOCIETY OF PHYSICS AND NATURAL HISTORY, FROM JUNE, 1875, TO JUNE, 1876.

By Dr. J. Müller, *President.*

Translated for the Smithsonian Institution by M. L. Duncan.

I.—MATTERS RELATING TO THE MEMBERSHIP, THE PROCEEDINGS, AND THE PUBLICATIONS OF THE SOCIETY.

Our society has experienced this year a great loss in the death of General Dufour, who was born in Constance, September 15, 1787, and died in Geneva, July 14, 1875. Switzerland loses in him one of its most popular and beloved sons and most illustrious citizens. After the publication of the biographical sketches in the *Journal de Genève*, there appeared a history of his life, a life in every respect complete, and marked by patriotism, disinterestedness, and general usefulness to his country. This biography, besides giving a sketch of the war of the Sonderbund, describes the brilliant career of the soldier, the classic reports of the general, and the conscientious labors of the scientist, whose military chart of Switzerland, requiring thirty-one years for its execution, is a masterpiece of successful perseverance; it likewise states the active part taken by the general in political, legislative, and administrative affairs, both federal and cantonal, as well as his indefatigable activity in military, scientific, artistic, and philanthropic societies. These publications, of course, render it unnecessary for me to enter into more general details.

Our society, of which the general had been a member since 1819, and to which he had contributed articles on the strength of iron wire, on the determination of the astronomical co-ordinates of Berne, and the high waters of the lake, published in volumes ii, ix, and x of our memoirs, has lost in him one of its most zealous members, who took a warm interest in its labors, and attended its meetings with military regularity and punctuality. The energy, kindliness, and uprightness, so faithfully reflected in every feature, and his uniform politeness, created in all a feeling of respect and affection never to be effaced.

Our society must also deplore the loss of two honorary members, M. Adolphe Brongniart, professor of botany, and one of the directors of the Museum of Natural History of Paris, and M. Ch. Desmoulins, of Bordeaux.

As to our publications, the first part of volume xxiv of our memoirs, a large half-volume of fifty printed leaves and twenty-eight plates, is

published, and contains the paleontological and geological monograph of the upper strata of the Jurassic formation of the environs of Boulogne-sur-Mer, by MM. de Loriol and Pellat, and the selection of new and but slightly known mosses by M. Duby. The second part of volume xxiv, and also the first part of volume xxv, are both in preparation for the press, in the first of which is a memoir by Professor Plantamour on the climate of Greece, and in the second a work by M. H. de Saussure on the *Gryllidæ*.

II.—MEMOIRS COMMUNICATED TO THE SOCIETY.

1.—*Astronomy and meteorology—Physical geography.*—Professor Plantamour gave an account to the society of a memoir which he published, with Professor Hirsch as collaborator, on the determination of the difference of longitude between the Simplon, Milan, and Neuchatel. During this work, he ascertained that the Swiss telegraphic lines are not as well insulated as the foreign lines, a circumstance that considerably reduces the velocity of the electric current, owing to the retardation of attraction of the armatures. Allowing for the changes of position that the axis of the instrument undergoes from a unilateral dilatation, caused by the presence of the body of the observer, and the corrections required by personal equations, those of the four observers, MM. Plantamour at the Simplon, Celloria at Milan, and Hirsch and Schmidt at Neuchatel, the following differences were established:

Between Milan and the Simplon	4′ 39″.238
Between the Simplon and Neuchatel	4′ 16″.824
Between Milan and Neuchatel	8′ 56″.062

The same member also submitted to the society a summary of his observations on the climate of Geneva. He found by examining the mean temperatures for the last fifteen years that they were higher than those of the thirty-five preceding years, so that the mean actually established for a series of fifty years must be increased by nearly 0°.2. C. (0°.3 F.). For every month of the last fifteen years, the mean temperature was higher than the mean temperature deduced from the previous thirty-five years, with the exception of the month of December, in which it was 0°.2 C. (0°.3 F.) lower. The greatest increase was 1°.23 C. (2°.21 F.), and occurred in the month of September. The mean temperatures of the whole series of fifty years furnish the following results: January, — 0°.079 C. (31°.85 F.); February, + 1°.598 C. (35° F.); March, + 4°.597 C. (40°.274 F.); April, + 8°.967 C. (48°.14 F.); May, + 13°.197 C. (55°.75 F.); June, + 16°.809 C. (64° 05 F.; July, + 18°.807 C. (65°.85 F.); August, + 17°.910 C. (64°.24 F.); September, + 14°.659 C. (58°.38 F.); October, + 9°.879 C. (49°.78 F.); November, + 4°.552 C. (40°.194 F.); December, — 0°.80 C. (30°.56 F.).

M. Plantamour, on the other hand, made an examination of his observations by dividing the year into seventy-three series of five days (the

pentades of Professor Dove) in order the better to detect the variations of the elements which had furnished the monthly mean temperatures, and to ascertain whether the meteorological theory by virtue of which M. Ch. Sainte-Claire Deville admitted the more or less regular return of anomalous cold spells at certain periods of the year, had or had not any foundation in fact. The plotted means of these pentades (or five-day periods) naturally gives a more undulatory line than the regular theoretical curve of the monthly means, and if there existed anomalous causes at certain fixed epochs, we should find the duration proper to each of those epochs traced in a manner altogether more decided in proportion as the observations are extended over a greater number of years. Now, M. Plantamour found that the very reverse was the case, and the curve of the mean temperatures of the pentades of the fifty years approaches more nearly the regular theoretic curve than that which had been calculated for the first forty years only. The annual mean for the last fifty years is 9°.345 C. (48°.821 F.). The warmest year of the series, 1834, had a mean temperature of 10°.99 C. (51°.78 F.); the coldest, 1851, one of 7°.85 C. (46°.13 F.). The period from 1826 to 1834 contains seven warm and two cold years; that from 1835 to 1860 gives twenty-two cold and only four warm years; and in the last fifteen years there have been thirteen warm and two cold. But there is no regularity in these variations, which, contrary to the ideas of certain meteorologists, afford nothing which substantiates any coincidence between them and the periods of eleven years which have been observed for the epochs of the minima and maxima of the solar spots.

Professor Gautier read a second account of the meteorological observations made at Labrador, at five different stations, by the Moravian missionaries. That of Hoffenthal gives the mean temperature of five years, from 1869 to 1873, at — 3°.03 C. (26°.55 F.), while the annual mean temperature of Edinburgh is + 8°.4 C. (46.47 F.). The winter and spring are very cold, while the summer and autumn are relatively mild. The mean diurnal variation, which is 4°.45 C. (8°.01 F.), attains at times to 22° C. (39°.6 F.). The extreme temperatures observed at the station of Roma were, on the 3d of February, 1873, — 35° C. (—31° F.), and August 21, + 24° C. (75°.2 F.). The greatest number of auroras observed there occurs in the months of January and February.

Professor Colladon read to us a work, which will be published in our memoirs, upon the great hail-storms, one of which devastated the canton of Geneva on the 7th and 8th of July of the past year, and the other Savoy and Bas-Valois, twelve hours afterward, and which coincided with violent storms between Lucerne and Zurich, and with another in Ardèche. The storms moved at a velocity of 50 kilometres (31 miles) per hour and the height of the hail-cloud was determined to be 2,000 metres (6,600 feet). M. Colladon recognized four different types of hail-stones.

The same member communicated an article upon the effect of a thunder-bolt on the trunks of two Lombardy poplars of different dimensions

on the plain of Eynard near Rolle. From the different details observed and the topographical position of the poplars, M. Colladon concludes: 1st, that the poplar is more likely to be struck than other trees; 2d, that when several poplars are standing in a group or in a row, the one nearest to water is the first struck, and this fact may be made available in discovering springs; 3d, the upper part of the poplar always remains intact, because its branches are good conductors of the electricity; 4th, the lightning passes between the sap-wood and the old wood, and escapes near the foot of the tree, laterally, by passing through the sap-wood leaving great spots around the holes through which it has passed.

Professor Forel, of Morges, announced to the society the first results of his observations of the *seiches* (variations of level), made at Morges by means of a recording limnimeter. The lake here presents longitudinal and transverse *seiches*, according as the periodic undulations follow the great or small axis of the lake. The normal *seiches* of Morges have a duration of ten minutes, whatever their amplitude may be. There are other *seiches*, less frequent, at Morges, having a duration of 70 minutes and of less amplitude, not exceeding one centimetre (four-tenths of an inch). M. Forel, by comparing these with those of Lake Constance and Lake Neuchatel, thinks that those of 70 minutes' duration are to be considered as longitudinal. Others, observed at Veytaux and Chillon, and which he accidentally recognized at Morges and Évian, whose duration is about 35 minutes, might be the longitudinal *seiches* of the large lake, oscillating from Chillon to the bar of Promenthon, and *vice versa;* those observed at Geneva of a duration of 30 minutes are probably the *seiches* peculiar to the small lake oscillating between the port of Geneva and the limit of the large lake; and, finally, the ordinary *seiches* of Morges and Évian, of 10 minutes' duration, are the transverse *seiches* of Lake Leman. The register indicates the passage of a steamboat, 20 minutes in advance, by waves of three-quarters to one minute in duration, and these waves, after the passage of the boat, continue to repeat themselves for an hour and a half at intervals of from one to two minutes.

2. *Physics and mechanics.*—Professor Soret communicated to the society the result of his study of the phenomena of diffraction in the circular gratings examined by him in the special case of equidistant circles. This result presents some analogy with those considered in a communication of the previous year. They produce a powerful concentration of the luminous rays along the whole length of their axis, and are capable of giving images of objects quite similar to those obtained through small holes.

The same member, in making a communication on halos, and especially on parahelia by reflection in crystals of ice, adverted to the fact that Bravais had considered two cases only, the prism with an elongated hexagonal base, and the star or regular hexagonal prism with re-entering angles. M. Soret added two new cases of parahelias, the prism of icicles with six regular sides, and prisms with elongated base, in which

the course of the rays is different from that which had been indicated by Bravais.

MM. Soret and Sarasin have made a summary of their work, inserted in the *Archives de la Bibliothèque Universelle*, No. 215, p. 253, on the rotatory power of quartz. The employment of the spectroscope, with the fluorescent eyeglass devised by M. Soret, admits of the extension of these limits to the ultra-violet part of the spectrum as far as the line N; and by the interposition of a plate of cobalt-blue glass, which arrests the mean red and orange rays, they succeeded in clearly distinguishing the lines *a* and A, by which they were then able to measure the rotatory power of quartz. These researches complete, as regards the extreme red and ultra-violet, the results obtained by Bloch and Stefan.

Mr. N. Lockyer, of London, an honorary member of our society, did us the honor of presenting the principal results of his researches in spectral analysis. This scientist mentioned the different spectral methods, the distinction which he established between the short and long lines of the spectra, the different conditions in which the vapors of bodies may be found, the modifications that the atomic grouping of those bodies may undergo, and the effects in the spectrum by which these modifications manifest themselves.

M. Raoul Pictet placed before us a communication on the application of the mechanical theory of heat to the study of volatile liquids, and the simple relations existing between latent heat, atomic weights, and the tension of vapors. There results from this work, which was inserted in the *Archives de la Bibliothèque Universelle*, No. 217, p. 66, 1st, that all liquids have the same cohesion; 2d, that the derivative of the Naperian logarithm of the quotient of the tensions in relation to the temperatures is constant for all liquids at the same pressure and temperature; 3d, that the latent heat of all liquids under the same pressure multiplied by their atomic weights at the same temperature gives a constant product; 4th, that for all liquids the difference of the internal latent heat at any two temperatures whatsoever multiplied by the atomic weight is a constant number; 5th, that the latent heats of all liquids are multiples of their specific heats.

Professor Wartmann presented to the society various models of Crooke's radiometer, manufactured at Bonn by M. Geissler. The radiations from a luminous source act upon the wheel, and repel the blackened faces. Nevertheless, by covering the latter, M. Wartmann showed that the rays from the sun, or from sources of high temperature, repel also the white faces. The interposition of colored glasses diminishes more or less the rapidity of the motion, which continues very rapid in the focus of a lens of sulphuret of carbon saturated with iodine. By acting upon one paddle only, M. Wartmann found that it remained in a state of equilibrium when the intensity of the radiation concentrated on the black face and the opposite white face is in inverse ratio to the absorb-

ing power of those faces. Light is not the cause of the phenomenon of the rotation of the wheel. This our colleague demonstrated by concentrating on the black face of the disk of an extremely sensitive radiometer the light of the full moon passing over the meridian. If a large lens or a concave mirror 0.55 metre (2 feet) in diameter is employed, the intense light of the focus renders the paddle motionless. The phenomenon has therefore a calorific origin. M. Wartmann also reported an experiment due to Dr. Schuster, according to which, when the motion of the wheel is impeded, it is the envelope of the radiometer, delicately suspended, that tends to turn in an opposite direction. There is therefore a mechanical reaction. Finally, M. Wartmann dwelt upon the fact that the degree of vacuum exerts a very sensible influence on the rate of each instrument under experiment. With the same radiometer, this vacuum does not appear to preserve the same value after the energetic action of the calorific sources.

M. Th. Turrettini submitted a communication on the different boring implements employed in tunneling St. Gothard, and explained the various apparatus, with working plans. The drill invented by himself, and bearing his name, is distinguished from others in two essential points: 1st. The system of air-distribution, effected by the reciprocating motion of the piston, which is produced by an arrangement of the piston and piston-rod in two separate pieces, and by the assistance of a system of differential pistons; 2d. The automatic advance and recoil of the machine is effected by utilizing the action of compressed air upon the percussion cylinder, in order to produce the tightening and loosening of the apparatus, which permits or stops that advance by the position itself occupied by the piston-rod. This machine makes 600 strokes per minute.

3. *Chemistry.*—Professor Marignac gave to the society an account of his researches, published in the *Archives*, No. 218, p. 113, on the specific heat of saline solutions. The specific heat depends on the nature of the acids and the bases of the salts, and also on other circumstances, which do not seem connected with the greater or less tendency of salts to combine with water to form definite and crystallizable hydrates. It is much less in general than the sum of the specific heat of the separate elements of the saline solutions; but the greater part of the acetates and acetic acid dissolved in water present the reverse. M. Marignac is of the opinion that the diminution of the specific heat of solutions is due to the disengagement of heat, resulting from a dissociation of the definite hydrates contained in them. This does not occur among alloys, because they cannot undergo dissociation so long as they are below their point of fusion.

M. Ador gave a statement of the research which he carried out in connection with M. Albert Rilliet, on the constitution of benzine. This investigation, with its numerous details, was inserted in the *Archives*, No. 219, p. 263.

M. Eugène Demole made a communication on the compound $C^4 H^9 IO$,

which is formed by the action of ethylene upon an alcoholic solution of iodine heated to a temperature of 65° C. (149° F.) This compound had been regarded by M. Baumstark as a derivative of ethyledine, and as being possibly a singular instance of transposition. M. Demole undertook the synthesis of this substance, making glycol his starting-point. The substances he employed were all prepared at low temperatures. They were glycol, iodinated glycol, monethylic glycol, and iodethylic glycol. Now this last agrees in its properties, its formula, and its vapor-density with the said compound in such a manner that we are forced to consider the latter a derivative of ethylene.

4. *Geology.*—Professor Favre presented to the society his chart of the Swiss glaciers of the Glacial period, projected on the scale of $\frac{1}{250000}$. This beautiful chart shows, 1st, the *névés* (partially congealed snow); 2d, the true glaciers of the Rhone, the Aar, the Reuss, the Linth, and the Rhine; and, 3d, the glacial terrain or glacial clays and sediments, the moraines, and erratic blocks. M. Favre designates as *glacier réservoir* (glacial basin) the zone of the *névés* occupying the high valleys, and *glacier d'écoulement* (flowing glacier) the zone of glaciers properly so called extending along the plains. As to the glaciers of the Rhone and the Rhine, the extent of the *glacier réservoir* was found equal to that of the flowing glacier. In addition, M. Favre deduced the depth of the glaciers from the position of the most elevated of the erratic blocks.

5. *Botany.*—We were presented by M. C. de Candolle with the result of his anatomical and physiological researches on the *Dionæa muscipula*, which led him to admit that here also, as among sensitive plants, the movement of the valves of the leaf is caused by the known phenomena of turgescence. It is only by the touch of one of the three hairs that the movement of the two demi-limbs is produced about the middle rib; for if the surface of the leaf is touched, the two valves do not close at all. It was therefore in the structure of the costa, and especially in that of the hairs, that M. C. de Candolle sought and found the details of cellular organization, which enabled him to refer the phenomena to the effects of turgescence. This work, accompanied by two plates, was inserted in the *Archives*, No. 220, p. 400.

6. *Zoölogy.*—Dr. Fol communicated to the society the principal results of his investigations into the nutrition, the mode of reproduction, and the means of locomotion of the Tunicates. These marine animals take nourishment by means of a thick and glutinous saliva. Their reproduction is complicated, for it is not until the third generation that the mother-form exactly reappears. The central style bears two kinds of buds: the central, attached directly to the axis, perform the functions of procreation and locomotion; and the lateral, further removed from the axis, whose office had not been known, are only organs of nutrition and respiration. When separated from each other, they soon perish. Dr.

Fol concludes from this that among the Tunicates, as well as the Siphonophora, there are swimming individuals and feeding individuals.

The same member, in presenting to the society a copy of his memoir on the *Pteropods*, gives some details of the Heteropods, which he is now elaborating for his second volume, and proves, contrary to the opinions of some writers, that the opening of invagination is persistent, and that it becomes a mouth. This mouth once formed, the embryo swallows the white of the egg; and this albuminous mass, after the hatching of the larva, serves for food.

M. Al. Humbert communicated to the society the result of the study of a blind Gammarus, found by M. Forel at the bottom of Lake Leman. As no intermediaries have been found between the seeing Gammarus of the lake at the surface of the water and the blind Gammarus which live from the depth of 50 metres (160 feet) to the bottom, M. Humbert does not think it can be admitted that this Gammarus is descended from the seeing species, and takes it for a variety of the *Gammarus puteanus*, a species which dwells at the bottom of wells in the vicinity of the lake.

Professor Bogdanow, of St. Petersburg, read to us a memoir on the successive history, through the different geological ages, of the fauna of European Russia, and accompanied his communication with numerous explanatory maps.

In addition to the works mentioned above, a large number of reports of recent and rare publications were made to the society, and a series of less detailed communications were presented.

M. Barbey gave some account of the California species of the genus *Epilobium*, which he is now preparing for the New Flora of California by Mr. Watson.

Prof. Alph. de Candolle took up and refuted the principal objections offered by M. Schacht to the theory of the sums of temperatures applied to the phenomena of vegetation. The same gentleman informed us that Professor Blytt, of Christiania, made observations in Scandinavia, which confirmed his own made in our Alps, and which lead to this: that of the valleys laid bare at the Glacial period, those whose glaciers retreated first, present a richer and more varied vegetation than those which remained a long time covered with ice. By consulting the notes collected by the Rigaud family and the employés of the guild-hall on the foliation of the chestnut of Treille, at Geneva, M. de Candolle was able to show that the time of the foliation does not vary with the age of the tree. The same scientist described to us a colossal tree of California, 276 feet in height and measuring 20 feet in diameter, a section of whose trunk was prepared for the exhibition at Philadelphia, and whose age was estimated at 2,120 years. He gave us some details of the extent of the culture of tea in the Indies, derived from the English journals. He showed us a bunch of grapes, of half-white and half-red berries, and

also a remarkable leaf and fruit-bearing stem of the *Diacontium pertusum*. The same member, when on the subject of the investigations of Professor Favre on the hill of Cassina Rizzardi near Como, remarked that the two Tertiary and Quaternary floras north of the Alps are distinctly separated by the Glacial period, while south of the Alps the Pliocene and Quaternary regions fade into each other, the Tertiary flora already presenting many of the plants of the present epoch. M. de Candolle likewise made a detailed report of the work of M. Francis Galton on twins in the human species.

Prof. A. N. Cazin, of Paris, honorary member of our society, gave an interesting recital, rich in details, of his journey to the island of St. Paul, to observe the transit of Venus.

Professor Dor, of Berne, made a detailed report of the experiments made under his direction by M. Decker, at the ophthalmological clinic of Berne, on the influence of the trijumeau in certain affections of the cornea.

M. Fatio described his researches, made conjointly with M. Adore, to determine the moment at which, with us, the winged form of the *Phylloxera* is produced. It was proved that the event takes place in the middle of July. These gentlemen also discovered a plant-louse, strongly resembling the *Phylloxera*, on the leaves of the maple.

M. Ernest Favre, while distributing a memoir on the Jurassic rocks of the Voirons, entertained the society with the discussions of geologists on the limits of the Jurassic and Cretaceous periods, and more particularly on the tithonic stratum of cephalopodic and coralline beds. Far from sharing the opinion of the geologists, especially the French, who see a great hiatus between the Oxford beds and the Cretaceous deposits of our Alps, M. Favre admits, with the other Swiss and German geologists, that at least for the Western Alps, and likewise the Voirons, these are all the equivalents of the Jurassic rocks; and if we are still unable to verify all the fossiliferous levels of the Jurassic basin, it is because the sediment was formed under different conditions, especially with regard to temperatures and currents. Professor Favre proves that by examining, on the spot, the hill of Cassina Rizzardi, near Como, where it was claimed that there were Pliocene shells in the glacial terrains he saw nowhere between Mendrisio and Chiasso that pretended mixture; that the hill in question bears no resemblance to a moraine; and that it is formed from a post-Glacial alluvium. The fossils found there were washed down by streams which drifted the rolling stones in which these fossils are imbedded. M. Favre likewise showed us specimens of the mineral known as the sapphire of the glacier of the Bois, and now classed by M. Specia with emeralds.

M. Fol described in the embryos of mole-crickets, before hatching, a larval heart analogous to that of the larva of mollusks. It is a contractile region of the ectoderm on both sides of the body. The same scientist gave some interesting details of the zoölogical laboratories of Naples and Rostock.

Professor Gautier kindly continued to inform us, as in times past, of new discoveries in astronomy and meteorology. Amongst other subjects, he mentioned Encke's comet, seven small new comets, three of which were discovered by M. Borelli, the astronomer of Marseilles, and a chart of shooting-stars observed by M. Ferrari on the night of the 11th of August, in the neighborhood of the constellations of Perseus and Cassiopia. He also alluded to a memoir published by the observatory of Athens on Coggia's comet, and gave an account of meteorological observations made at the observatory of Berne. Colonel Gautier submitted to us an analysis of a work by M. Trouvelot, an American astronomer, on a new category of solar spots, the veiled spots.

M. Raoul Pictet mentioned the second volume of M. Hiern on the mechanical theory of heat. He also communicated to the society the fact that sulphurous acid, after being used for several days in the ice machine prepared by M. Pictet, and recently tested at Toulon and Marseilles, was found much purer and more limpid than at the time of its introduction into the machine, and no longer held sulphur in suspension, and absolutely ceased to act upon metals, especially copper. The same member, in giving an account of the trials he had made to determine the conditions of equilibrium of a heavy body in a gaseous current, pointed out to the society that there was in the interior of the conical gaseous jet an ovoidal space, in the interior of which heavy bodies, such as balls of different substances, remain in equilibrium, taking up a very rapid rotatory movement.

Professor Plantamour commented before the society upon a publication of M. Tacchini on the Italian mission to the Indies to observe the transit of Venus.

Professor Prévost gave an account to the society of a memoir that he had recently published in the Bulletin of the Medical Society of Switzerland on cases of alcoholic delirium observed in the cantonal hospital of Geneva, during the year 1874–'75. The same member mentioned the thesis of Dr. David on apomorphine, and also the researches of M. Vulpian on the singular effects of the paralyzation of the movement of the heart. He showed to us a photograph of the brain of an aphasiac patient observed at the hospital of the canton of Geneva. This brain, in confirmation of Broca's opinion, presented a lesion in the third convolution of the left frontal hemisphere. On this occasion, Dr. Prévost reaffirmed that a lesion in the island of Reil might have the same consequence. He showed to the society a rat that had been perfectly preserved for two years by means of an injection of six grains of chloral. Moreover, M. Prévost presented to us the circular of the committee charged with the organization of the fifth session of the periodical International Congress of the Medical Sciences to meet at Geneva, September 9, 1877, and gave some details of the congress.

M. Risler presented an analysis of M. Ebermayer's work on the influence of forests on climate. The same member furnished us with some

details of the effects of a stroke of lightning upon five telegraphic posts, placed at a distance of 30 metres (100 feet) apart. The mark left by the fluid was a spiral; this passed from four to five times around the post, but the post next to the last, which was of ash, was less injured, and the fracture was in the form of a straight furrow.

M. Sarasin gave an account of a work by M. Weber on the specific heat of carbon, boron, and silicon (see *Archives*, No. 216, p. 407).

M. H. de Saussure furnished some details on the fauna of Turkistan, presenting at the same time the first number on the Orthoptera of that country, now being published by M. Tchenko. The same gentleman mentioned the scientific collections which he had had the opportunity of seeing at Vienna.

Professor Soret gave us some information about the zoölogical laboratory of Arcachon.

M. Turrettini spoke of the tension of the overhanging granite of St. Gothard. The parts laid bare press toward the vacancy, and break up, often with violence, which made it necessary to arch the whole length of the tunnel, contrary to anticipation.

Professor Wartmann described to the society the results obtained by M. Lockyer from observations on the variations of the calcium spectrum.

REPORT ON THE TRANSACTIONS OF THE GENEVA SOCIETY OF PHYSICS AND NATURAL HISTORY, FROM JUNE, 1876, TO JUNE, 1877.

By Adolf Favre, *President.*

[Translated for the Smithsonian Institution by M. A. Henry.]

Gentlemen: Called for the second time to render an account of all that concerns our society, I have the pleasure to state that the number of members has considerably increased, notwithstanding our previous sad losses.

In presenting to you a summary of the condition and proceedings of the society, as well as of the various subjects which have engaged your attention during the seventeen meetings of the year, I will follow the usual order.

I.—OBITUARY NOTICES.

Joseph de Notaris, made an honorary member of our society in 1871, was born in 1805 at Milan, was of a noble family, and died at Rome on 22d of January, 1877. During his medical studies at the University of Rome, where he received the degree of doctor, he acquired an ardent taste for natural history. In 1832 he was made professor of botany at the Lyceum of Milan; in 1836, assistant in the Museum of Natural History of Turin; in 1839, professor at the University of Genoa, and director of the Garden; and finally, in 1872, he accepted the same position at Rome. This was contrary to the advice of his friends, who feared, not without reason, disappointment in the hopes he had conceived of the restoration of the Garden and of science in the new capital of Italy. His nomination to the Senate was but a small compensation for the numerous difficulties he encountered.

As soon as he was established at Turin, J. de Notaris commenced the publication of botanical works, particularly upon Cryptogamia. The memoirs devoted to the mosses have been collected in a magnificent volume, published at the expense of the municipality of Genoa, and constitute a reliable system of Italian Bryology, to which the Academy of Sciences of Paris awarded the Desmazières prize.

The other branches of Cryptogamy were also pursued with careful and accurate research by the learned professor. J. de Notaris was the soul of an important publication, "*l'Herbier cryptogamique*" (the Cryptogamic Herbal). The flora of Liguria, as well as the fragmentary records of Egyptian Agrostography, equally attest his profound knowledge in every branch of botany.

Two days after the death of Joseph de Notaris, our society sustained the loss of Jean Christian Poggendorff, added to the number of her honorary members in 1874, as an expression of her sympathy with this illustrious savan, on the occasion of a *fête* celebrated in commemoration of the fiftieth year of the publication of the annals bearing his name.

Born on the 29th of December, 1796, deceased at Berlin on the 24th of January, 1877, this learned physicist labored unceasingly from 1821 until the time of his death, which came to him after a short illness.

During his laborious youth, his uncommon energy led him into a path in which his active perseverance, his just and clear understanding secured the esteem and respect of all savans. In 1820, he was matriculated at the University of Berlin; in 1834, received the degree of doctor of philosophy; was nominated professor at the same university; and in 1839, was made a member of the Academy of Sciences of Berlin. Still a young man, he studied chemistry, and soon devoted himself to physical research, especially in the line of electricity.

In 1824, he commenced the "*Annales de Chimie et de Physique*" (Annals of Chemistry and Physics), which succeeded the *Annales* of Gilbert. The 166 volumes which have appeared in the course of fifty-three years contain many of his own works, as well as additions, criticisms, and elaborations of the memoirs of other scientists. This important publication did not prevent him from engaging with Liebig in the formation of a dictionary of chemistry, while at the same time he was giving to the world various biographical sketches and a biographical dictionary.

The death of Poggendorf is a great loss to science. He not only contributed to its advance by his original investigations, but rendered easier for others the researches to be made in physical science, still a maze of confusion which every day renders it more necessary to reduce to order.

II.—THE SOCIETY.

Our society has added this year to its regular members Dr. Pierre Dunant, M. Schiff, Dr. Julliard, and M. Zahn, all four professors of the university. These elections carry the number of regular members up to fifty, the limit according to rule of admission, so that at present our society is full.

From the ranks of the free associates we have had the misfortune to lose Messrs. Charles Eynard and Prévost-Martin; we have, however, added to them Charles Golaz, William Favre, Charles Rigaud, Emile Pictet, Domaine Roux, and Ernest Covelle.

Professor Wartmann was elected president for the year 1877–'78, and Messrs. Marignac, Edward Sarasin, and Philippe Plantamour were continued in their offices of secretaries and treasurer, and received the thanks of the society for the manner in which they had fulfilled their trust.

You have, gentlemen, taken an important step, it may be well to mention here. In view of the constant increase in the number of ordinary members and free associates, and the consequent insufficiency in the

supply of our Memoirs, it was decided that there should no longer be a general distribution, but that the members and associates should be advised, as soon as a volume appeared, that it could be obtained at a certain place appointed, and if not claimed at the end of two years it would be at the disposal of the society. This decision does not affect the distribution of our Memoirs abroad.

The committee of publication has been charged to make every effort to obtain for the society former volumes necessary to complete our series.

The society has published during the past year the second part of volume XXIV of its Memoirs, containing articles by M. Plantamour and M. de Loriol. To this must be added the first part of volume XXV, containing a memoir of M. H. de Saussure; and we have still in press the first part of volume XXVI, containing memoirs of M. Duby upon new species of mosses, of M. E. Favre upon the geology of the Crimea, and other interesting matter.

In regard to the memoirs in competition for the prize founded by A. P. de Candolle, to be presented in 1879, the society caused the following notice to be published in various journals (*Archives des sciences physiques et naturelles*,* March, 1877).

"PRIZE FOUNDED BY AUGUSTIN PYRAMUS DE CANDOLLE FOR THE BEST MONOGRAPH UPON A SPECIES OR A FAMILY OF PLANTS.

"A competition is now opened by the *Société de physique et d'histoire naturelle de Genève* for the best unpublished monograph of a species or family of plants.

"The manuscripts may be written in Latin, French, English, or Italian. They must be sent, postage paid, before the 1st of October, 1879, to Professor de Marignac, corresponding secretary of the society at Geneva. Members of the society are not admitted to the competition.

"The prize is 500 francs. It may be reduced or not awarded in case the articles do not correspond to the conditions of this notice.

"Geneva, February, 1877.

"A. FAVRE,"
President of the Society.

III.—LABORS OF THE SOCIETY.

1. *Physics.*—Professor Plantamour has given an account of a work published by him with Professor Wolf, of Zurich, upon the telegraphic determination of the difference of longitude between the observatory of Zurich and the astronomical stations of Pfändler (near Bregenz) and of Gäbris (Appenzell). The astronomer Oppolzer assisted in this work. During these

* In future we will mention this review simply as *Archives*.

observations it was observed that the pendulums of M. Wolf and M. Oppolzer were influenced in their course by the electric register which accompanied them, while the pendulum of M. Plantamour, constructed by M. Hipp, was not in the least disturbed. In fact the probable error for each combination of longitude is from seven to eight thousandths of a second. The measures gave for the difference of longitude between the three stations:

	m.	*s.*
Pfändler–Zurich	4	53.691
Gäbris–Zurich	3	40.070
Pfändler–Gäbris	1	13.621

M. Raoul Pictet has proved an anomaly in the law of the diffusion of gases, in the fact that sulphurous acid passes through india rubber with greater facility than hydrogen; a balloon of india rubber containing sulphurous acid will soon be emptied. By filling with this gas a glass tube closed at the upper end by a sheet of india rubber, and plunging the lower end of the tube into mercury, the rapidity of the escape of the gas may be measured by the ascent of the mercury in the tube.

Professor Soret has entertained the society at two sessions with some new researches made, with M. Edward Sarasin, upon the rotatory polarization of quartz, particularly for the ultra violet rays, by means of a spectroscope with a fluorescent eye-piece. This instrument was described in the *Archives* in December, 1876. The results of the labors of MM. Soret and Sarasin are given in the *Comptes rendus de l'Académie des Sciences*, t. 83, p. 188.

Professor Wartmann made a communication upon the extrapolar deviations observed upon mercurial conductors, whether vats or troughs. He produced a very sensible current by placing the two extremities of the wire of a galvanometer in the neighborhood of the pole of a current passing through a trough or vat filled with mercury, but beyond the line of the poles.

Lucien de la Rive presented a work upon the specular reflection of surfaces covered with hairs, considering them as cylinders with a circular base. The author demonstrated that a surface covered with cylinders presented other brilliant points than those of the surface itself. (*Archives*, 1876, t. 57.)

Professor Marignac made in his laboratory some experiments upon capsules of tempered glass; one of them very well resisted the gas flame, but half a minute after the extinction of the flame it exploded like a Rupert's drop.

M. Theodore Turrettini observed that a mixture of snow and chloride of magnesium gives a temperature of—34° C. (—29° F.), while the mixture of snow and chloride of sodium gives only —18° C. (—2° F.) An important use may therefore be made of a product very abundant in mother-waters which has hitherto been thrown away. The double chloride of

potassium and of magnesium is also a product of the mother-liquors which is not deliquescent, and which presents some advantages over the chloride of magnesium. It gives a temperature of —32° to —34° C. (—26° to —29° F.)

M. Turrettini showed that the temperature to which may be carried a solution of salt or of chloride of magnesium in water is the same as that produced by salt or by this chloride when mixed with snow: thus the solution of chloride of magnesium freezes only at —34° C. (—29° F.)

M. Turrettini also exhibited and explained the diplograph, a writing-machine for the use of the blind, invented by M. Ernest Recordon of Lausanne, and constructed by the Genevese Society for the Manufacture of Physical Instruments. This machine forms, at the same time, characters in relief for the blind, and ordinary printed letters for those who can see; so that the blind can correspond with each other, and those who have sight with the blind.

2. *Meteorology and terrestrial physics.*—Professor Plantamour presented to our society a *résumé* of the principal results of a work upon the barometric observations, the hygrometric state of the atmosphere, the nebulosity, the rain, and the wind observed at Geneva during the fifteen years comprised between 1861 and 1875. These researches, which were considerable in extent and important in results, were published in the twenty-fourth volume of our Memoirs, under the title of *Nouvelles études sur le climate de Genève* (Recent investigations of the climate of Geneva), and were discussed by Professor Gautier in the *Archives*, 1877, t. 58. They formed a sequel to a volume published by M. Plantamour, in 1863, upon the climate of our country from 1826 to 1860.

Dr. Forel while pursuing, as we know, with great perseverance his investigations of Lake Leman, succeeded in discovering the form of the seiches—oscillations of the water in the direction of the length and the width of the lake. This exposition is equally applicable to the movement of the waters of the lakes of Brienz and of Wallenstadt. The observations which served as the base of these calculations were made with a limnimeter register. (See *Archives*, 1876, t. 56, 57, and 59.)

To carry the study of this oscillation of the water further than can be done in a single locality, Professor Plantamour examined this movement at Secheron near Geneva. He recognized its existence, but it was produced here in a contrary direction from that at Morges. When it was low at Morges it was high at Geneva and *vice versa*. Professor Plantamour caused a limnimeter register to be established at Secheron. (*Archives*, 1877, t. 58.)

Dr. Forel has also studied the transparency of the waters of Lake Leman. He determined it by measuring the depth at which a white disk ceased to be visible in the water, or by measuring the minimum depth at which a photographic plate experienced no alteration. A white disk of 25 centimetres (10 inches) in diameter disappeared, from

May to December, at 6m. 6 (22 feet); in winter at 10m. 1 (33 feet;) in March, 1875, it was necessary to sink it to 17m (56 feet.) The limit of photographic action was found to be 45m (148 feet) in summer, and 100m (328 feet) in winter. According to the author the transparency of the water of the lake depends, first, upon the temperature; second, upon the proportion of organic matter in suspension in the water. The latter is more abundant in summer than in winter, because the waters of the lake in the first of these two seasons present strata of different temperatures, producing differences in density, and the result is that the organic matter, also differing in density, will seek a stratum of a corresponding density and will be there held in suspension. In winter the temperature of the water being more uniform, the substances are retained in much less quantity. (*Bulletin Soc. vaudoise des Sc. nat.*, 1874, t. xiii; 1875, t. xiv; and *Comptes rendus de l'Académie des Sciences*, 1877, t. 84, p. 311.)

M. Raoul Pictet has presented, in regard to the intermittent fountain of Vichy, a theory by which he has been enabled to explain the singular movements of waters more clearly, since he has succeeded in constructing an apparatus which produced them in miniature. This fountain proceeds from a tube which descends to a depth of 197m (351 feet), at the base of which, therefore, there must be a pressure of ten atmospheres. The eruption of water mingled with gas is produced for about an hour, rises to ten or twelve meters (33 or 39 feet), and ceases for five or six hours. If the pipe reaches a little below the most elevated portion of an impermeable vault which covers a part of the sheet of water, the gases which are generated by the waters of Vichy accumulate in the vault, drive the water to the lower edge of the conduit and escape with it over the latter. (See *Archives*, 1876, t. 57.)

M. Theodore Turrettini has made known the results obtained by M. Pictet and himself in the fabrication of transparent ice by means of the machine employed by the firm of Raoul Pictet and Company. As slow freezing of the water could not be managed, MM. Turrettini and Pictet tried agitating the water under the pneumatic pump in order to drive out the air, but the middle of the block of ice formed was more or less opaque on account of a sort of crystallization. M. Turrettini has at last succeeded in obtaining some perfectly transparent ice by causing globules of air to pass through the water to be frozen, in a continuous current. These large globules of air seemed to carry away with them the small air-bubbles, which even more than the crystallization appeared to cause the non-transparency of the ice.

3. *Geology and chonchology.*—Professor Renevier has exhibited a chart of the Swiss Alpine Club on a scale of $\frac{1}{50000}$, colored geologically, prepared for the federal commission of the geological chart of Switzerland. It includes the most elevated parts of the Vaudois Alps, the rocks of Diablerets, of the Muveran, &c., and extends along the right shore of the Rhone to the north of Martigny in Valais, from the village of Ardon to that of Ollen, to the north of Bex. This when published will be accom-

panied with numerous raised sections, prepared with the greatest care, so as to represent the country in all its details. The inversions of the strata are so numerous in this region as to be almost the normal condition; not less than thirty-six geological stages may be counted in this chart, from the crystalline schists to the modern alluviums. Among the new facts contained in a memoir published by Renevier, on the appearance of this chart, we mention the discovery of a tooth of *Otoduk* in the sandstone of Taveynnaz. This is the first time a fossil has been observed in this rock. (*Archives*, 1867, t. 59.)

Professor A. Favre has given some explanations of the geological chart of the canton of Geneva, scale $\frac{1}{25000}$, and submitted them to the society. The various strata which compose this region have been already described elsewhere. The most ancient rock is the sandstone, which is divided into the red, or lower, sandstone, and the gray sandstone, containing traces of lignite and gypsum.

The ancient alluvium rests upon the sandstone, and appears at various levels; it is composed, at its base, of clay without pebbles, and with lignite surmounted with a formation of worn pebbles and sand, often in a state of hard conglomeration. M. Favre has recently discovered in it scratched pebbles and insertions of a rock of a glacial character. (*Bulletin Soc. géol. de France*, 1875, iii, t. 723, and *Archives*, 1877, 58, p. 18). If such observation are multiplied they will probably acquire such importance that a refutation may be deduced from them of the hypothesis of two glacial periods. The glacial stratum resting upon the ancient alluvium is composed of clay more or less gravelly; it constitutes the largest part of the surface of the canton. Erratic blocks are found upon it, all from the valley of the Rhone, while there appear to be none from the valley of the Arve.

The post-glacial alluviums are composed of gravel and of sand from terraces more or less elevated upon the borders of the lake and of the rivers. They contain many pebbles, broken and indented. This destruction or decomposition of pebbles, near the surface of the soil, is without doubt one of the principal causes of the formation of vegetable earth. We find in the canton much sandy soil, fine sand, and small gravel. These are of different ages, and formed of various rocks. Particles of oxidized iron are found in them, which attest their Alpine origin. Peat and marshy ground are not of frequent occurrence in the canton. M. E. Favre has presented *Some remarks upon the origin of ancient alluvium.* He has indicated the principal characteristics, and has especially dwelt upon the sections of the Bois de la Bâtie and the quarry of Mategnin. He concludes that the formation of this stratum, entirely composed of worn pebbles, was intimately connected with the extension of ancient glaciers, and that its presence at various levels on the sides of the mountains and in the bottoms of the valleys is because the ice covered very uneven ground. (*Archives*, 1877, t. 58.)

M. de Loriol has exhibited two species of *Echinoïds* from Maurice Isl-

and, one belonging to the genus *Brissus*, the other, the *Echinolampas Alexandri*. This genus made its appearance with the Tertiary formation. The species, numerous in the Eocene, less extensive in the Miocene, rarer still in the Pliocene, number four at the present time. (See vol. XXIV of our *Memoirs*.)

A few years hence the conchologists of our country would be much puzzled to explain the appearance of two fresh water shells, *Paludina vivipara* and *Planorbis corneus*, if M. H. Fol had not taken the precaution to inform our society that he had put in the salt marsh of Sionnet a certain number of these mollusks to see whether they could be acclimated.

4. *Animal physiology and medicine.*—Professor Schiff has sought to modify the hypothesis of M. Dubois Raymond, of the electric nature of the nervous agent, and to determine whether electric currents are produced in the nerves of living animals. Using very sensitive apparatus and operating upon the sensitive nerve of a frog decapitated just at the moment of the experiment, the result was negative. In other experiments M. Schiff employed the muscles of the thigh of a frog cleaned and arranged so as to serve as a connection between two electrodes. He observed no current, and the learned professor concluded that none was produced, in the absence of all lesion in the uncut nerves. He, however, immediately perceived, the formation of a current when the nerve was merely pinched. After the hypoglossal nerve of a dog has been cut and the wound healed, the nerve is no longer in a normal condition. Uncovered at the moment of experiment it gives variable electric effects. In operating upon the pneumogastric nerve of cats and rats under the influence of alcohol and curara, kept at the temperature of the surrounding air, M. Schiff observed no current; but, on binding or tying the nerve, the current was formed immediately. M. Schiff thinks, therefore, that in the normal condition of the nerve and in the state of immobility of the living animal there is no current; that when the current is produced, it results from the death of the nerve, or from nervous activity and the contraction which accompanies it.

The same learned gentleman addressed the society upon the properties of nicotine as a poison, and the action of the liver under the effects of this poison. The nicotine injected under the skin of a dog produced death in a few moments. When the nicotine was forced through the liver, its effects were weakened; the nicotine is destroyed by this organ. The nicotine doubled has very nearly biliary activity. Until now only iocyamine was known which produced similar effects; and according to M. Lautenbach the action of the liver is more complete upon this poison than upon the nicotine. One-sixtieth of a drop of this substance is sufficient to kill a frog, after the liver has been tied, although one-twentieth is sufficient in the ordinary state. The tying of the *vena porta* of a dog, of a cat, or of a rabbit, produces the death of

the animal in about two hours and a half, with circumstances similar to those caused by morphine or any other narcotic. If two cubic centimetres of the blood of a dog, the *vena porta* of which has been tied, are inserted in a frog, and in another frog the same quantity of the blood of a dog intact, at the end of three hours the first frog will be dead, while the second will be in good condition. M. Schiff concluded from this that the action of the liver destroys the nicotine, and that there is constantly produced in the digestive organs of man and of animals a poisonous substance which would destroy them in a very short time if they were not continually saved by the action of the liver.

Professor Zahn submitted to the examination of the society a preparation of the costal cartilage of man, showing a pigmentary infiltration of the cells. This infiltration is a new characteristic of this cartilage, and has not been mentioned in any treatise on pathological anatomy, although M. Wechl and M. Wirchow have both mentioned the pigmentation. It is four years since M. Zahn first noticed this infiltration; since then he has often observed it; it exists in half the men over forty years of age. General pigmentation has been observed by him only in two cases of severe ictarus. (*Archives*, 1877, t. 58.) M. Schiff adds that he has been able to produce this pigmentation by the slow compression of the biliary livers.

Dr. Prévost has given a description of a case of aphasia observed in a young girl, who, although attacked with a right hemiplegia, retained all her intelligence. The aphasia continued after the hemiplegia disappeared, and the patient could pronounce words only when she sang them.

Professor Plantamour drew the attention of the physiologists to the difference in the power of perception of the transit of stars according to the inclination of the head. He remarked this fact several times, and again recently during some observations made with Colonel Orff, who having difficulty in seeing on account of the position of the eye-glass, bent more or less his head. The result was a very noticeable difference in the appreciation of the transit of stars.

M. H. Fol gave an account of his researches in regard to the fecundation of eggs, especially of sea-urchins. The details of these remarkable researches may be found in several articles. (*Archives*, 1877, t. 58, p. 439; *Comptes rendus de l'Académie des Sciences de Paris*, 1877, t. 84, p. 268, 357, and 659.)

M. V. Fatio has made known certain variations in species among fishes, such as alterations in the form of the mouth on account of the medium in which these animals live, as well as correlative modifications in various parts of the body.

5. *Botany.*—Professor Candolle has given some details of a work he has just completed relative to the family of *Smilaceæ*. This is a part of a work entitled *Monographiæ Phanerogamarum*, which he prepared with his son and several other assistants. This family is well defined by its characteristics, and is divided into three genera: *Heterosmilax*, *Smilax*, and

Rhiphogonum. M. de Candolle has been able to prove that several species have been described under two names, and has made known fifty-five new species. The present geographical distribution of plants of this family, combined with our knowledge, unhappily imperfect, of fossil *Smilaceæ*, allows the presumption that dispersion in former times was much greater than at present. Now the *Smilaceæ* are found only in the district comprised between Japan, India, New Caledonia, and the Sandwich Islands. From this limited region to Brazil, the Cape, and the Azores, only a few genera or subgenera are found.

M. Duby submitted a work accompanied with plates relative to a genus and eighteen new species of moss from Japan, the Philippine Islands, and Maurice Island. They belong to the genera *Batranica*, *Orthotrichum*, *Schlotheimia*, *Pterobrium*, *Hypnum*, and *Henoniella*. M. Duby called attention to the large number of mosses found at the same time in Maurice Island and the Sunda Islands. (See part 1 of vol. XXVI of our *Memoirs*.)

M. Marc Micheli has given account of the most recent investigations relative to insectivorous plants. (*Archives*, 1877, t. 58, p. 393). M. Duby mentioned on this occasion that other plants exuded digestive acids, among others the *Petunias*, which capture certain insects by means of glutinous glands.

6. *Statistics*.—Dr. Dunant called the attention of the society to the change in the population of the city of Geneva from 1845 to 1872.

At no period has the increase by naturalization been as great as from from 1850 to 1860. The proportion of the population under fifteen years of age and that above sixty has increased; that of adults has diminished.

The number of marriages among the Genevese diminishes, that of marriages between strangers and Genevese remains the same, and that of marriages between strangers increases. There are fewer births among the Genevese than among the Swiss of other cantons and among the foreigners. Illegitimate births are more frequent in the foreign population and the Swiss of other cantons than in the Genevese population. The mortality is studied with care in this great and concientious work. (See *Journal de Statistique Suisse*, 1876, Nos. II and III.)

The society has listened to numerous reports upon works published in various countries, and in regard to which the members of the society, after discussion, passed judgment more or less pronounced. These discussions animated the sessions, and drew the attention of the members to labors outside of their especial studies.

The following is a list of these communications: Professor Gautier, observations made in various observatories, of the velocity of the stars, the zodiacal light, a new star in the constellation of the Swan, the double star of the Centaur, the climate of Berne, inundations in Switzerland in June, 1876, &c.; Colonel Gautier, solar protuberances; Professor Soret, photographs of the moon, defects of the retina, and the

telephone; Dr. Forel, the frost of the 12th of November, 1876; Professor Wartmann, apparatus for ascertaining the impulsion that a spark of induction passing through a rarefied gas is capable of producing in a longitudinal direction; M. A. Achard, the form and properties of the articulated losange of Peaucellier; composition of certain waters, according to Girardin; M. E. Sarasin, a writing-machine; M. R. Pictet, a work of M. Dufour, of Lausanne, upon the cure of a person blind from birth, and upon the theory of vision (*Archives*, 1877, t. 58); Professor Schiff, various experiments upon the hereditary transmission of certain artificial lesions; M. Fol, memoirs upon the heteropodes, upon pulmonated terrestrial mollusks, and upon a microtome which allowed the making of fifteen or sixteen cuts of an embryo of one-fifth of a millimeter in thickness; M. Fatio, axolotls, the preparation of delicate skeletons cleaned by the tadpoles of frogs; Professor De Candolle, the law of botanical nomenclature; Professor Muller, lichens; M. M. Micheli, influence of manure upon the composition of grains.

With this list, gentlemen, I close the report I have the honor to present to you. We have cause for satisfaction that the increase in the number of members, of the memoirs presented, and of our publications, manifests a growth of activity in our society.

ANTIQUITIES OF JEFFERSON AND CLEAR CREEK COUNTIES, COLORADO.

By George L. Cannon, *of Idaho Springs, Colo.*

During the last three years I have examined a large number of aboriginal structures in the counties of Jefferson and Clear Creek, and as the prehistoric remains of Clear Creek County are of small extent, I shall devote the greater part of my communication to a description of those in Jefferson County. A good idea of the topographical features of the district in which these remains are situated may be obtained by consulting Chittenden's map of the eastern base of the Rocky Mountains, published in Hayden's Survey of Colorado for 1874. It consists for the most part of elevated plains, interspersed with prairie bluffs and sandstone "hogbacks." Most of the remains apparently belong to quite a modern period, that is to say, within the space of twenty or thirty years; still, in some cases, judging by the depth to which the stones composing them have sunk and by the thickness of the superincumbent soil, we may give them an antiquity of a century or more. The greater part of them are situated on the tops of hills, commanding a view of the adjacent plains, but occasionally we find some in low lands, in the vicinity of springs, where good water can be obtained. The first to be described, and perhaps the most numerous class of relics, are the so-called "fire-places." They consist of several flat, irregular stones, discolored by fire, arranged so as to form a hearth, and are identical with the fireplaces which the modern Indians have in the center of their wigwams. They are scattered promiscuously over the plains, without much reference to location, save such as a party of campers would choose.

Next in importance to the fire-places are what are locally denominated "Indian circles." They are usually constructed of bowlders arranged in the form of a rude circle, about a yard in diameter, with a cavity a foot or two in depth, hollowed out in the center. The most common opinion is that they were used by the Indians as fire-places. The modern Indians are said to encamp on sites similar to those in which these circles are found, and in some cases surround their fires with a wall of stones, to prevent them from being extinguished by the wind. Some have supposed that they were occupied by signal-fires, and this may have been the case, as most of them are in situations that would be suitable for the purpose. Again, it has been thought that they mark the graves of some prominent Indian warrior or chief, although it was not the usual custom of the Indians to bury their dead, but rather to place the corpse on an elevated platform.

One of these circles, on North Table Mountain, appeared so much like a grave, that a party of excursionists made an ineffectual attempt to open it, in hope of finding something to reward their pains, as Indians frequently bury utensils and weapons with the dead. The wall surrounding the supposed grave differs from that of other circles in being constructed of flat slabs of basalt, instead of bowlders of quartzose rock, and on the southern side of the inclosure stood a slab of trachyte, which had probably been brought from the crater of an extinct volcano a mile or more distant, and had the appearance of a tombstone. The ground for some distance around gives forth a hollow sound, as if there were a cavity beneath, and on a hill near by is a mound apparently intended as a mark to guide in finding the grave. In connection with the circles we sometimes find heaps of stones rudely piled together, whose use has not as yet been conjectured. In many places are to be seen spots where the Indians appear to have been encamping and making their arrow-heads and tools. In most cases only a few scattered chippings of flint and quartzite occur, as if they had encamped for the night and chipped out a few arrow-heads for the morrow's chase, while other places appear to have been occupied for quite a length of time, and the ground in their neighborhood is thickly scattered with fragments and flakes of the various stones used by the Indians in making their implements, accompanied occasionally by chipping-axes, hammers, skin-scrapers, mortars, and pestles. These camps are usually situated in fields, in the vicinity of running water, and also in the neighborhood of a hill or steep bluff, to which they could retreat in case of attack. In a small grove of cottonwood trees near Apex, Colorado, the Indians appear to have made, in former times, great quantities of tools and arrow-heads, for the ground all around is thickly strewn with tools, chippings, and arrow-heads, some of the latter made of beautiful stones and of the most exquisite workmanship. Within the space of an acre or two we have found about a hundred arrow-heads and ten axes and hammers. The Indians seem to have carried on quite a trade among themselves, in order to procure the materials for arrow-head making, as some of the chippings found in their encampments are from stones which cannot be found within several miles of this place, and some, I think, have been brought from distant localities. Although the Indians used several kinds of stone in the manufacture of arrow-heads, yet they seem to have had a preference for quartzite, chalcedony, and jasperized wood, probably on account of their superior hardness, and may have made others from handsomer but less durable stones only for purposes of barter, as the Indians of California exchanged arrow-heads made of bottle-glass.

The following minerals were employed in the manufacture of tools: moss-agate, chalcedony, carnelian, wood-opal, sapphirine, petrified wood, flint, red jasper, brown quartzite, agatized wood, obsidian, yellow quartzite, purple and yellow jaspers, smoky quartz, chert, jasperized wood, red quartzite, besides several undetermined silicates. While speaking

of the encampments, it will be well to describe some of the most prominent Indian implements found in this neighborhood, because we may safely say (if we except a few scattered tools and an occasional arrow-head lost in hunting) that they are all to be found in these places. The most abundant implements are chipping-axes, hammers, skin-scrapers, mortars, and pestles, but others occur to which we are unable to apply names, owing to our ignorance of their former uses. The chipping-axes are usually made from pieces of quartzite, worn or chipped down to an edge, and were most probably employed in chipping out flint-flakes to be used afterward in the manufacture of weapon-points. The hammers are simply oval stones, sometimes grooved on one or more sides, for the purpose of attaching them to handles. The skin-scrapers found in this vicinity do not differ much, if at all, from those procured in other localities. The so-called "corn-mills" consist of a flat slab of rock containing on its upper surface an oval depression, and a roundish stone supposed to be a pestle. These mills were probably used in pulverizing roots, and perhaps corn, although I hardly think the Indians of this section cultivated corn, or any other sort of grain. Sometimes small pieces of fine-grained quartzose rock are found, which appear to have been used in polishing or sharpening weapons. A friend of mine states that he found near Idaho Springs an earthern jar, a foot below the surface, containing a quantity of reddish paint, and I have found at the encampment at Apex small pieces of a reddish colored sandstone, which, on being wet and rubbed on the flesh, leaves a slight red stain. I have been informed that the Indians used it for paint, but I hardly think this can be the case, as the sandstone is quite gritty and would scratch the flesh considerably. The Indians probably had many other tools besides those which I have mentioned, but being composed of wood, or of some other perishable material, they have decayed. There are said to exist in some localities large circular depressions in the ground, where, according to old settlers, the Indians were in the habit of holding war-dances. On the top of a steep bluff near South Table Mountain is a semicircular wall of basaltic bowlders about 20 feet in length and a foot or two in height, and as the bluff on which this wall is situated is in the center of a large prehistoric encampment, it may have been used as a breast-work for the purpose of defense. On the side of a steep hill, near Green Mountain is what appears to have been an Indian road; a path about a yard in width has been made by clearing away the stones from the side of the hill and placing them as a border on either side. For the greater part of its course the path goes straight up and down the hill, but near the bottom of the hill it takes an abrupt turn, making nearly a right angle with its former course.

ANTIQUITIES IN WISCONSIN.

By Moses Strong, *of Mineral Point, Wis.*

Traces of the mound-builders are found extending northward in Dunn, Barron, Polk, Burnett, and Douglas Counties. The localities, however, are not numerous, and the mounds are usually circular.

Commencing in the territory south of that above indicated, the mound shown in Fig. 1 was observed a short distance west of the village of Orion, in Richland County. It is situated on the southeast quarter of section 35, township 9, range 1 west, on a low, sandy ridge, which separates the Wisconsin and Eagle Rivers; and about a quarter of a mile northwest of it is the mound shown in Fig. 2.

It is, perhaps, an open question whether these mounds are effigies of men or birds, but after a careful examination of them and of many others, I incline to think they are representations of the human form.

So much, and so much only, of the article of Mr. Strong, on the prehistoric mounds of the western part of Wisconsin, had been written by him before the 1st of August, 1877. On the 18th of that month, while engaged in the prosecution of his geological researches, he was drowned in the Flambeau, a branch of the Chippewa River, leaving unfinished the article of which he had commenced the preparation. The field-book left by him contains, however, the notes of his examinations of several mounds, with rough pencil sketches of their forms and dimensions. These notes and sketches being in my possession as his father and administrator, I have had drawings prepared representing the mounds, which, with copies of the original field-notes explanatory of them, are herewith submitted.

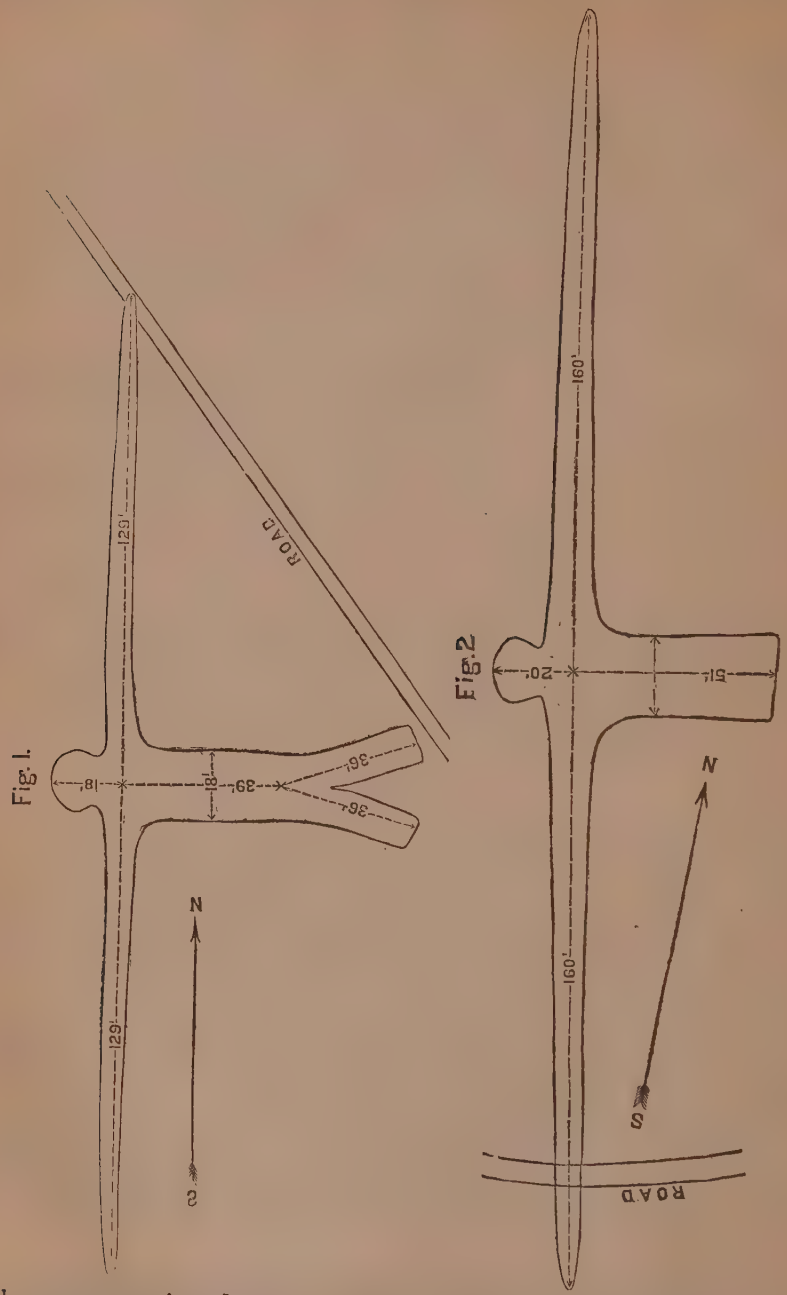
Fig. 3 is a sketch representing mounds near Wauzeka, in Crawford County, which are referred to in the field notes, as follows; "The following shows a number of mounds near Wauzeka. There is only one which is at all remarkable in appearance; the rest are the usual round and straight mounds. The large one has been excavated in three places and scraped away on its western end. It seems to consist principally of sand. Examined May 31, 1875."

The accompanying pencil-sketch (Fig. 4) was made by Mr. Strong, on a scale of 120 feet to the inch, from his notes, and is given as he prepared it, instead of attempting to make another draught.

All that is contained in the field-notes concerning this group is written upon the margin of a sketch, and is in these words: "Map of mounds at Hazen's Corners, on the Black River road, made June 5, 1875, in N. E. $\frac{1}{4}$ sec. 35, T. 8, R. 6 W. The mounds lie in the brush and woods, on the crest of the ridge."

The sketch of Fig. 5 was also made by Mr. Strong, in pencil, and is given as he prepared it, together with the following in relation to it, which is all the field-notes contain: "N. E. $\frac{1}{4}$ of sec. 21, T. 8, R. 6 W.;

lies on crest of ridge alone. Saw several long, straight mounds on crest of ridge in N. W. ¼ of sec. 21."



The accompanying drawing (Fig. 6) was taken by tracing from the sketch made in the field, and the proportions are probably not exact, but can be corrected by the dimensions marked upon it.



Fig. 3.

The field-notes accompanying this drawing are as follows: "Man-shaped mound in N. W. ¼ of sec. 21, T. 8, R. 6 W.—very short legs, thick body, and long arms. There are three more exactly similar to this, a little further west in a ploughed field." Then follow in the field-notes rude sketches of the three, without dimensions, of which tracings are given (Figs. 7, 8, and 9), and the only notes are as follows: "Three effigies in a ploughed field."

The next two drawings (Fig. 10 and 11) are pencil-sketches of bird-mounds made by Mr. Strong, on a scale (No. 10, of 50 feet to an inch, and No. 11 of 60 feet to an inch). The following remarks in relation to these mounds is all the information that the field-notes supply:

"Bird-mound in S. E. ¼ of sec. 19, T. 8, R. 6 W. No. 10."

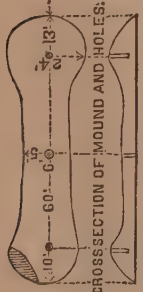
"No. 10 lies about 50 feet N. E. of No. 11, and is 50 feet from tip to tip of the wings."

"No. 11 is a bird. Lies on crest of ridge on end of it, toward the Miss. River, where the ridge splits up."

The field-notes contain the following in this connection: "The creek which runs through secs. 27, 28, 29, 30, T. 8, R. 6 W. forms a little table about a mile above its mouth, which is covered with mounds, but so overgrown with brush that it is hard to make them out. The valley is narrow and walled in with cliffs of lower magnesian limestone 200 feet thick. Potsdam sandstone does not appear. Timber in this part of the country is scattering white-oak."

The next drawing (Fig. 12) is made from a sketch in the field-notes.

In reference to this drawing (Fig. 12) the field-notes contain the following: "Monday, June 7.—Mounds on the Black River road on S. E. ¼ sec. 24, T. 8, R. 6 W. Mounds are covered with growth of small black oak. Two hundred feet east of No. 12 is a straight mound 250 feet long—course N. E."



The accompanying drawing (Fig. 13) is taken from a field-sketch, made by Mr. Strong in his field-notes, and the other (Fig. 14) is intended to be like it. The field-notes contain the following: "Fifteen feet N. E. of No. 13 is another exactly like it, situated in the same way. They lie 25 feet S. E. of Black River road."

From the field-notes it is evident that these two mounds (Figs. 13 and 14) are in the east half of section 24, township 8, range 6 west.

The next drawing (Fig. 15) is made from a field-sketch, which is accompanied by the following: "S. W. ¼ sec. 19, T. 8, R. 5 W. No. 15 lies about one mile beyond No. 13, on the north side of the road."

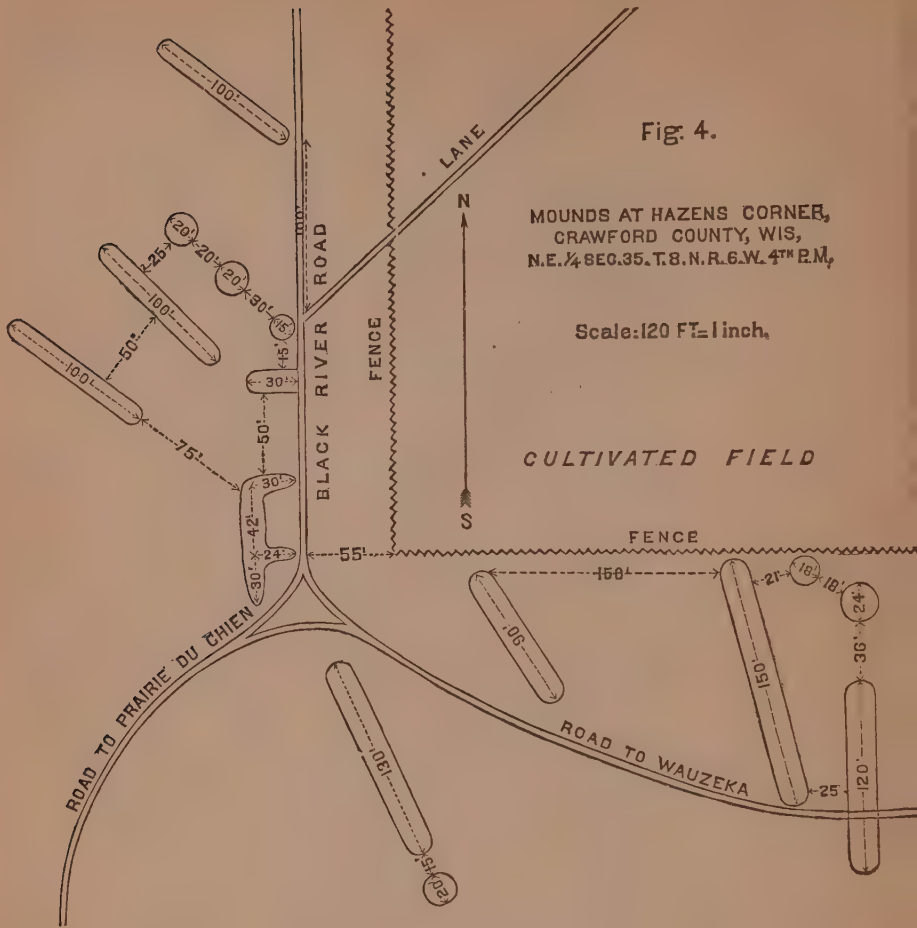
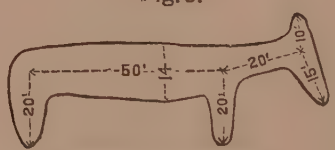


Fig. 5.



Scale: 50 FT. = 1 inch.

Fig. 6

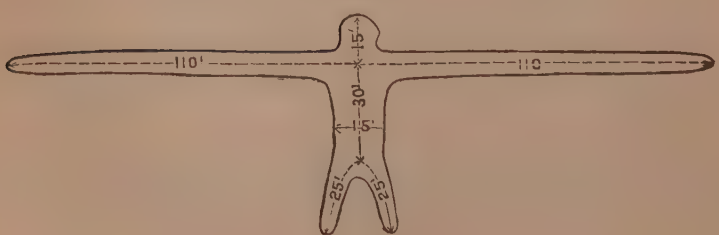


Fig. 7.

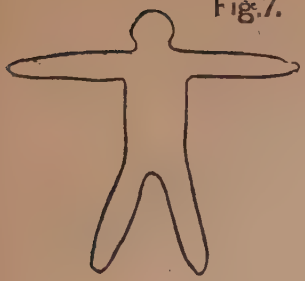




Fig. 8



Fig. 9.



Fig. 10.

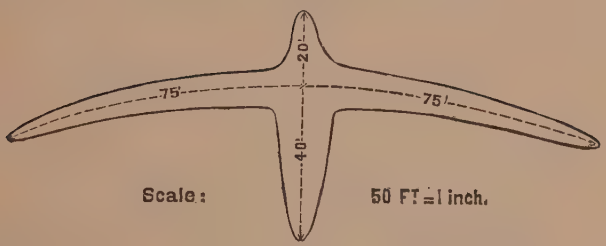


Fig. 11.

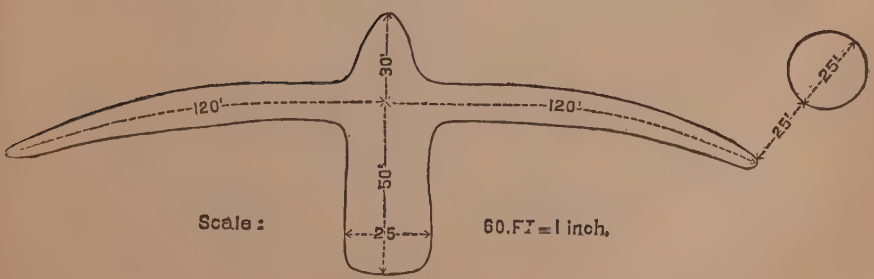


Fig. 12.

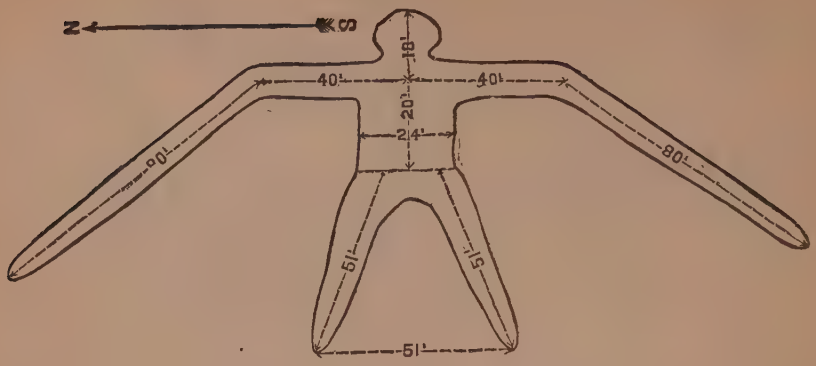


Fig. 14.



Fig. 13.

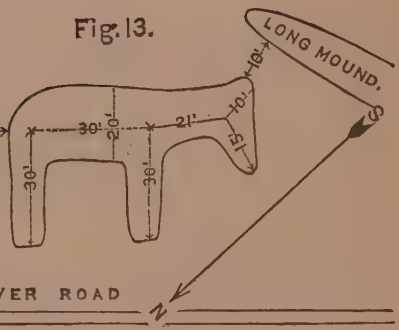
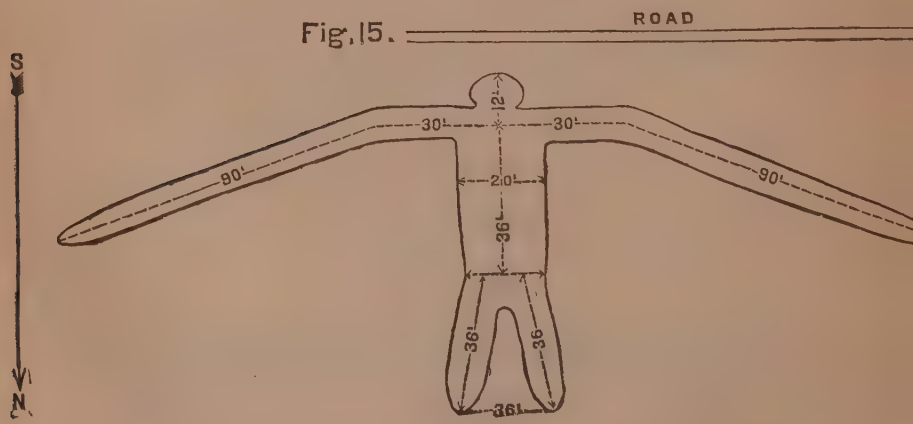


Fig. 15.



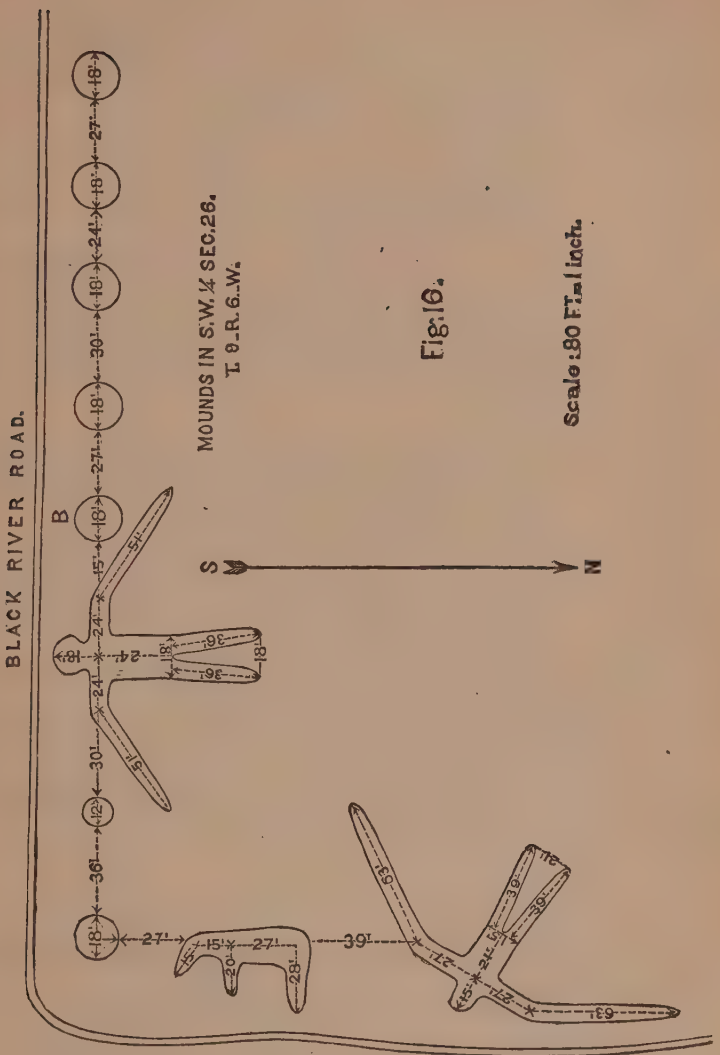

BLACK RIVER ROAD.
B
MOUNDS IN S.W. ¼ SEC. 26.
T. 9. R. 6. W.
S
N
Scale :80 Ft. = 1 inch.

Fig. 16.

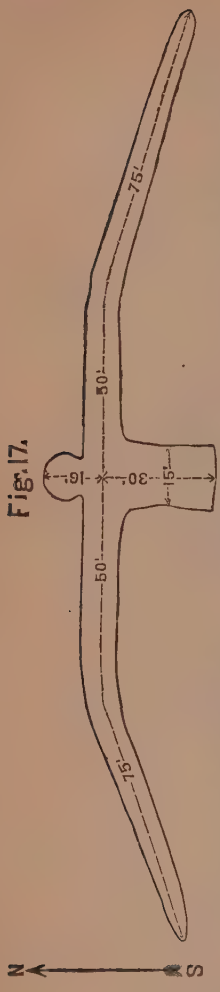


Fig. 17.

The field-notes contain the following: "Thursday, June 10.—The ridge in sec. 26, T. 9, R. 6 W., is very narrow and steep on each side. Ridge is not over thirty yards wide, and the crest has numerous long, straight mounds on it conforming to it. The view from here is very fine. The mound-builders chose the ends of the ridges overlooking the Miss. River for their mounds. Saw a man-shaped mound near ¼ post between secs. 36 & 35, T. 9, R. 6 W."

Fig. 16 is a pencil-sketch drawn by Mr. Strong from the sketch contained in his field-notes:

The field-notes contain the following in relation to the drawing (Fig. 16):

"On the man-effigies the body and breast bulge up much higher than the rest. They look like a man lying on his back. Mounds all about three feet high. Arms and legs on these mounds about ten feet wide. Mounds in S.W. ¼ sec. 26, T. 9, R. 6 W., on crest of ridge."

"Saturday, June 12.—Went with Dr. Wight (Dr. O. W. Wight, then chief geologist) and father and George (Geo. Haven, assistant), and dug up mound (B, Fig. 16). The mound was made of clay, and easy digging. Found in bottom a thin stratum of hard clay, with a whitish substance which may have been decayed bones."

The accompanying drawing (Fig. 17) is made from a sketch found in the field-notes.

The field-notes contain the following in relation to this mound (Fig. 17):

"Man-mound on west fork of the Kickapoo River, in N. W. ¼ sec. 27, T. 12, R. 3 W."

THE MOUNDS AND OSTEOLOGY OF THE MOUND-BUILDERS OF WISCONSIN.

By J. N. DeHart, M. D., *of Mendota, Wis.*

Along the northern and eastern shores of Lake Mendota, or Lake of the Great Spirit, as it was called by the aborigines, many mounds are found, whose outlines are quite distinct, and represent the bear, deer, squirrel, and other animals, while a few of them imitate birds of various kinds. Some of the latter resemble the eagle, and are of very large dimensions. There are three mounds of this character in close proximity to each other; the body of the largest bird measures 100 feet in length, and 30 feet in width at the junction of its wings; while its tail

expands to the width of 40 feet, and the wings are each 300 feet long. The head is perfectly formed, so that the beak is quite distinct, and measures 15 feet in length. The other two eagles are somewhat smaller in all of their dimensions. Near the left wings of two of these birds, the form of a deer, 3 feet in height, is easily recognized. The body of the deer is 65 feet long, and the legs measure 14 feet in length; the head measures 12 feet from the tip of the nose to the origin of the antlers. These latter are each 10 feet long, with branches extending at nearly right angles from their center. Near the right wing of the third bird is the form of a bear.

In Sauk County, one mound is made in the form of an animal, which also resembles a squirrel, whose body is 160 feet long, with a remarkably long tail, measuring 320 feet.

Dr. Lapham, in his "Antiquities of Wisconsin," describes a mound which represents a turtle measuring 6 feet in height, 56 feet in length, with a caudal appendage 250 feet long. Another ancient mound is in the form of a night-hawk, whose expanded wings measure 240 feet in length.

While many of the ancient mounds represent different kinds of animals and birds, others are circular in form, and a few are oblong.

There are several ancient mounds located upon the northeastern shore of Lake Mendota and on the lawn of the former residence of Ex-Governor Farwell.

The largest of these mounds is circular in form, and measures 188 feet in circumference and 35 feet from the base to its summit. It is elevated 96 feet above the lake, and was the first explored. It is the highest of all the mounds in this group, and located in a central position. From its elevated site it could have been used for observation and as a means of communication by signal with other mounds in the adjacent country. The view from its summit extends from 8 to 10 miles in all directions.

In commencing the explorations, it was decided to sink a perpendicular shaft, about 6 feet square, through the center of the mound from the apex to the bottom. After removing the surface, a rich black earth, similar to what is found along the shore of the lake where muck accumulates or on the prairie bottom, was encountered to the depth of 5 feet. At this depth and on the western side of the shaft stones, composed of magnesian lime and yellow and red sandstone, were found. Below this layer of earth there was a bed of yellow clay 4 feet in depth, through which a course of similar stones was found, arranged in a circular manner, and passing off toward the opposite side of the shaft. Some of these stones were quite large, and presented a flat surface, while a few of them bore indications of having been broken from the stratum of limestone, which is found just below, along the shore of the lake. These had been worn quite smooth in places by the continual washing of the water. Beneath the bed of yellow clay a course of rich earth, similar to the first layer, was found. This deposit was 4½ feet in depth. After

removing two feet of this course, some ashes were found lying quite near the layer of stones previously described. Charcoal and decayed wood in small quantities were unearthed; also a few shells and small pieces of flint. The earth was very dry and underneath the stones was very hard, and had the appearance of having been baked. Another foot of earth was removed, when the skeleton of an adult mound-builder was discovered at the southeastern corner of the shaft, in a sitting posture, resting upon a natural bed of yellow clay. Several pieces of the cranium, the inferior maxillary, vertebræ, ribs, and bones of the extremities were found, but none of them where wholly perfect. There was a mold in the earth, in which the skull had lain, but only portions of the bones were found. The body of the inferior maxillary was very large. The vertebræ were larger than those of the present human type, and the right humerus was perforated at its inferior extremity. The perforation on the anterior surface of the bone is surrounded by a gradually-receding border or margin. This bone is no doubt of great antiquity, and is very much decayed, the superior extremity having disappeared. In no case did I find any of the long bones wholly perfect, but all of them were broken near the center of the shaft, the other extremity not being found. It is hardly probable that this is due to decay, but as others have previously stated, may point to some superstitious rite or custom connected with the sepulture of the dead. This was the only humerus found with either extremity in a nearly perfect condition. Two small sections of the shaft of the other humerus were removed from the tumulus, but they did not present any anomaly.

The shafts of ten tibiæ found in this mound presented a remarkable flatness. In comparing the specimens found near Lake Mendota, in mound No. 1, with those reported by Mr. Gillman (see Report 1873), I find they are very similar; and while his measure $\frac{48}{100}$ of an inch in comparing their antero-posterior diameter with the transverse diameter, my specimens measure $\frac{52}{100}$ of an inch in the same diameter.

The bones of the cranium crumbled into many pieces when removed, and could not be put together so as to give a proper idea of its conformation and structure.

Underneath the remains of this mound-builder were a few inches of black earth, the removal of which revealed a course of stones similar to those found elsewhere in the mound. These stones lay upon a natural bed of yellow clay. As there were no evidences that it had ever been disturbed, and being below the level of the surrounding ground, it was not thought best to continue the shaft any deeper.

A drift was then made into the side of the mound, about 3 feet above the level of the surrounding surface, and to the width of 8 feet. After removing several feet of black earth, a similar course of stones, as previously described, were found; charcoal, ashes and decayed wood were discovered near them. On continuing the drift toward the center of the tumulus and near the shaft previously sunk, the remains of the skeleton

of a young mound-builder were found, probably not more than six years of age, and in a sitting posture. Only a few pieces of the cranium, several vertebræ, portions of the long bones of the extremities, and the superior and inferior maxillary were found. Several teeth were still in the alveolar process of the superior maxillary. Many pieces of flint, a few shell beads, and two fossil teeth of some animal, about one inch and a half long, were taken from the same vicinity. About one foot from these remains three pieces of ancient pottery were discovered. The largest piece measured 4½ by 5½ inches, and bore indications of having been part of the bottom of an earthen bowl. It was smooth on the inner surface, and marked externally by oblique lines, such as are frequently found upon the ancient pottery of the mound-builders.

The drift was continued toward the center of the tumulus as far as the shaft and then downward to the natural bed of yellow clay. Just before reaching the shaft, and after removing a course of magnesian limestone and yellow and red sandstone, a few bones of the cranium and portions of the long bones of another adult mound-builder were found. These were all that remained of this skeleton.

Many flat stones were found below the skeleton, upon which lay charcoal, ashes, and decayed wood. Large pieces of flint were quite numerous in this vicinity. Some of the stones had been exposed to such intense heat, that they crumbled to pieces on handling them. At the junction of the drift and the perpendicular shaft a pillar of earth was encountered. On removing this, a few bones of the foot of the first skeleton were found, together with large quantities of ashes, charcoal, decayed wood, and flints. A flat disk of stone, one-fourth of an inch in thickness and 4 inches in diameter, was removed from the earth forming the pillar. Similar stone disks have been met with in other ancient mounds, and are supposed to have been used by them in playing games.

Mound No. 2, circular in form, and located a few yards from mound No. 1, was then explored. It was about 5 feet high and 130 feet in circumference.

A drift 6 feet wide was made in the side of it, on a level with the surrounding ground. After removing the surface, a layer of gravel and pebbles to the depth of 1 foot was encountered, and at the summit there was a course of sand, dipping downward; this was followed by a course of black earth about 3 feet deep. Below this there was a third stratum of gravel and sand; then a course of earth to the depth of 1 foot. A thin stratum of sand was then removed, which revealed ashes, charcoal, and pieces of flint lying upon an altar of stone resting upon a bed of yellow clay. This altar was about 1½ feet below the natural surface. The excavation was continued 1½ feet deeper, but nothing was found.

A few feet from the summit of this mound there was a tree, measuring 5½ feet in circumference. In the side of this tree, and fastened in the bark, was a stone pestle. This had evidently been carried upward though the mound by the growth of the tree. The bark of the tree was

broken and the pestle removed. It was formed of a very hard, gray, granite, and measured 6 inches by 8 inches.

Owing to the rapid approach of cold weather, no further examination of these mounds was made. Next spring it is my intention to continue the explorations, and I hope to find more evidences of the existence of this ancient race.

PITS AT EMBARRASS, WISCONSIN.

By E. E. Breed, *of Embarrass, Wis.*

There is a series of pits on the northwest of the northwest section 10 and northeast of the northwest section 10, township 25, range 15 east (town of Matteson). They are in an irregular line; general direction, from northwest to southeast; from 4 to 6 rods apart. Quite a number are in pairs. The depth, as found by excavating the earth that had caved in, was originally from 4 to 5 feet; diameter, 3 feet. In almost every instance the earth was thrown out on the southwest side; soil sandy. A few years ago the land was covered by a heavy growth of timber, principally hemlock. Trees over two hundred years old grew on the earth that had been thrown out. The chain is broken by a small pond, perhaps 10 rods across, but follows a sandy ridge most of the way.

MOUNDS IN DELAWARE COUNTY, IOWA

By M. W. Moulton, *of Monticello, Iowa.*

So far as now known, the credit of discovering these mounds belongs to Mr. Rynerson, of Hopkinton, and the following brief description will convey some idea of their size and relative position: Assuming a starting point which I shall call A, as the most important mound of the system, from A in nearly a westerly course is a row of mounds ten in number, exclusive of A. This row curves a little for the purpose of following the highest land, the surface descending both north and south. Starting again at A, and following a course west of south about 20 degrees, for 36 yards, we come to an earth-work of continuous elevation and 40 yards in length. After an opening of 10 yards, this elevation continues 50 yards farther, making a work 100 yards in length, including the opening. Leaving the south end of the long earth-work, and stepping 18 yards due west, then following a line parallel with the long earth-work 54 yards, we come to the first of another set of mounds six in number. These are in an exact line. From the most southern of these, and extending nearly in a western course, is still another set of six. These are also in a straight line. The north and south rows are parallel to each other. It will be observed that these three sets form

nearly a hollow square, with the opening to the west. The area inclosed is about ten acres. Returning again to our starting point at A, and pursuing a northeasterly course, we find the most remarkable set of the system, eleven in number, extending from A in nearly a straight line. This set, with the exception of three, is almost perfectly preserved, rising abruptly from a comparatively level surface to a height of about four feet, round and symmetrical, and with a base diameter of about 30 feet. The system, as a whole, is well preserved.

EARTH-WORKS ON THE ARKANSAS RIVER, SIXTEEN MILES BELOW LITTLE ROCK.

By Mrs. Gilbert Knapp, *of Little Rock, Ark.*

When we came into possession of this plantation thirty years ago, it was an unbroken wilderness. We were attracted to the place by the immense artificial mounds and a wall similar to our levees, from 6 to 10 feet high, inclosing ninety acres, and forming a half circle on the lake bank, which might have been, at one time, the Arkansas River. In the wall are two openings, both deep pools of water.

Within the area, between the lake (which is three miles long) and the wall, are numerous mounds, but only two of great size; the heights are variously estimated; one, which was called 100 feet high, we have cultivated for twenty years. It produces more than a bale of cotton, so you may imagine the size. As the years go by, it washes away, and rude relics are picked up. It was certainly a place of sepulture, for human bones are found tier upon tier, mingled with those of deer and other animals. They are of great age, and crumble on being exposed to the air.

One of the elevated mounds, still covered with trees, sometimes gives forth a ringing sound as if it were hollow, when wagons are driven round it. These two larger mounds are situated sixteen miles southeast of Little Rock, in the alluvial valley of the Arkansas, where the black deposit is 10 feet deep, and no stones or pebbles exist naturally; but the bygone race who made it their home, brought crystals, flints, jasper, granite, and sandstone from Hot Springs.

ANTIQUITIES OF KANSAS CITY, MISSOURI

By W. H. R. Lykins, *of Kansas City, Mo.*

We have lately made a discovery here of a number of Indian mounds which are evidently of great antiquity. They are situated on the north side of the Missouri River, in the angle of the Great Bend, upon the high bluffs commanding a view of the country about the mouth of the

Kansas River, directly opposite. They are found for several miles up and down the river, scattered in groups of three and five. They are of two kinds, one made entirely of earth, the other has an interior construction of stone, but outwardly they are all similar in appearance. They are of an irregular oval shape, about 60 or 75 feet in length at the base, and from 4 to 6 feet high. All have had a heavy growth of timber on them. On the apex of one, a stone mound, I noticed a large burr oak about 5 feet in diameter, and on another, the decayed stump of a black walnut about the same size.

We have not yet made any extended investigation of these mounds, but examined partially one group of five, three of which were of earth and two of stone and earth. In the center of No. 1, an earth mound, at a depth of about five feet, we found a human skeleton, lying north and south, with its face to the east. The bones were so fragile that we could only get them out in fragments. The skull fell to pieces as soon as exposed to the air; we, however, saved the frontal bone in tolerably good condition. We did not notice any very marked peculiarity as to these bones except their great size and thickness, and the great prominence of the supraciliary ridges. The teeth were worn down to a smooth and even surface. The next one we opened was a stone mound. On clearing off the top of this we came upon a stone wall inclosing an area about 8 feet square, with a narrow opening for a doorway or entrance on the south side. The wall of this inclosure was about 2 feet thick; the inside was as smooth and compactly built and the corners as correctly squared as if constructed by a practical workman. No mortar had been used. At a depth of about 2 feet from the top of the wall we found a layer of five skeletons lying with their feet toward the south. The bones were in the same condition as those of No. 1. We saved two or three of the skulls in a tolerable condition, by coating them with thick varnish as soon as exposed. We did not go any deeper in this mound; but there are probably other layers of bones beneath the ones we uncovered. Mound No. 3 was also a stone mound, and contained a stone wall inclosing a room about the same size as that in No. 2, but was built in a very rough manner as compared with the other. We removed the earth of about half of this inclosure, but found nothing inside but a mass of charcoal, ashes, and burnt human bones. The walls and earth around them appeared to have been subjected to long-continued heat, and the place had evidently been used for cremation or sacrifice. No. 4 was a very large earth mound. In the center of this, at a depth of four feet, we found a small pile of loose stones covering a few handfuls of broken and calcined human bones, too fragmentary to make anything out of them. This was the extent of our explorations at this time. No flint implements, pottery, or any other relics were found with the bones. A farmer living in the vicinity reports having ploughed up a lot of pottery; but it was, unfortunately, all destroyed by his boys, who threw it on a burning log-heap to see if it

would "stand fire." No flints are found on the surface in the neighborhood of the mounds; but the farmers say that when their fields become old and worn the plough often turns them up from the yellow clay beneath the soil. A few rude stone axes and arrow-heads were found in the ravines, where they had been washed out of the bank. A gentleman, living near the mounds we opened, has a spear-head, which he found, when digging a foundation for his house, at a depth of over 3 feet. His house is situated on one of the highest points in this locality. In our excavations into the mounds we did not find any of the black surface-soil which covers the land here; the earth was entirely homogeneous, and was of the loess or bluff formation which covers these hills. The mounds have the same depth of soil on them as the surrounding surface, and there is no trace of any pits or depressions from which the earth might have been taken to construct them.

THE MOUND-BUILDERS IN THE ROCK RIVER VALLEY, ILLINOIS.

By James Shaw, *of Mount Carroll, Ill.*

That part of the State of Illinois called the Rock River country is, in many respects, one of the most interesting portions of the great Northwest.

The early settlers and explorers found this valley thickly peopled with Indian tribes, who regarded it as a favorite hunting and fishing ground. Black Hawk and his brother, the Prophet, here made their last desperate struggle.

Those remains which can hardly be called prehistoric, such as the later Indian tribes and the early French explorers left, will be dismissed with a passing notice. In some localities, the early settlers well remember the evidences of an Indian cultivation of the soil, where well-defined hillocks in parallel rows marked the old corn fields. Immediately east of Rock Island, and at various places in the rich alluvial bottom lands, these were found perfectly distinguishable. They are mostly worn away now by the rains and subsequent cultivation. The writer has also an iron lance-head, picked up many years ago on the prairies of this county, whose wooden shaft was well-nigh rotted away, evidently used by the Indians in spearing the buffalo, when they pastured on our prairies. In several localities old decayed camp-kettles, of brass or zinc, have been found buried near the edges of streams, which were evidently used by the early explorers and voyageurs before the country was settled by white men. Two of these were recently found near the banks of Rock River, between Dixon and Sterling, and are now in the collection of Dr. Everett, of the former city.

There is also abundant evidence that this Rock River country was densely peopled by the mound-builders. They have left their remains

everywhere, on all its most beautiful spots. Stone implements, copper weapons and ornaments, and the remains of their plastic art are also frequently found.

The antiquities of that portion of Rock River flowing through the State of Wisconsin and of the Wisconsin counties lying immediately north of this part of the State of Illinois have been fully described by Mr. Lapham, in Vol. VII of the Smithsonian Contributions to Knowledge. But the antiquities of the Southern Rock River Valley and of Northwestern Illinois yet remain comparatively unknown.

It is the design of the writer to indicate briefly the character and extent of the works of the mound-builders in this region of Illinois.

The first thing to be noticed is the contrast between the character of the remains found here and those of Wisconsin and the Ohio Valley. The animal figures and effigies of the former State are almost wanting here. With the exception of a large turtle mound within the limits of the city of Rockford, and a few rude serpent-shaped structures in another part of the district examined, the mounds are round or oblong in form. Nothing like the great field-works, fortifications, and sacred inclosures of Ohio, or such as are found at Aztalan, in Wisconsin, exist, so far as known, on or near the shores of Southern Rock River. But the oblong and common round mounds, some of them of large size, may be counted by thousands. The valleys of the Fox and Wisconsin Rivers, not a great distance from us, are very similar to this section of country in their physical geography. The upper valley of Rock River very much resembles the lower; the mound-builders swarmed over them all; yet the effigy mounds are peculiar to a portion of Wisconsin, and are bounded by geographical limits, outside of which they are seldom found.

Commencing with Winnebago County, the most interesting remain is the Turtle Mound, within the city limits of Rockford, already referred to. It is noteworthy on account of its great size and fine proportions, but more so because it is the only one of the kind on Lower Rock River. It is generally known as the "Turtle Mound," but the resemblance to a headless alligator is more striking. The following are its dimensions: Length, 150 feet; width, opposite fore legs, 50 feet; width, opposite hind legs, 39 feet; length of tail, 102 feet. The figure lies up and down the river, on a line almost north and south, the tail extending northward. The body rises into a mound as high as a standing man. The feet and tail gradually extend into the greensward. The measurements across the body at the legs include those appendages, which are only a few feet long. The effigy, whether of alligator, lizard, or turtle, seems to be headless, and no depression in the surrounding soil would indicate that the materials of which it is constructed were obtained in its immediate vicinity. Near by this is an oblong-shaped mound, and several round mounds. The oblong mound is rather remarkable, 130 feet long, about 12 feet wide at the base, and 4 feet high.

Thus it will be seen that three types of the mounds are found in this county. The oblong ones are not numerous. Circular mounds, from 10 to 15 feet in diameter and from 2 to 5 feet high, abound. An interesting group of large ones almost surrounds the oblong and turtle mound above referred to. There is a large group of the circular variety on the north bank of Rock River, about six miles below the city. They exist in many places along the stream in scattered groups. But the locality where they are met with in the greatest numbers is on the banks of the Kishwaukee, in the southeastern part of the county, near the confluence of the two streams of that name. Scores of them are scattered about here, and scores more have been well-nigh obliterated by the plowshares. This was a favorite spot with the mound-builders. Many relics, including some of copper, have been picked up, disturbed in their places of deposit by continued cultivation and plowing.

Jo Daviess County contains great numbers of these mounds. Dr. J. S. Love, of Hanover, writes me that there are from three to four hundred around that place, mostly on or near the banks of Apple River. The locality is one of wild beauty, and such as would attract the mound-builders and become a swarming center of population. Among these are two well-marked chains of fortifications—a rather unusual kind of works for this part of the country.

From excavations made in these mounds have been taken many beads; arrow-points and spears made from red, white, and black chert and flint; one large battle-ax, 8 inches long, 5 inches wide, and 2 inches thick; pestles for pounding corn; one chisel of flint, and one carved stone pipe. No galena, so far as I know, has been found in these mounds, although they are not far distant from the famous Elizabeth diggings. Mounds abound near this latter place, but I have no special information of their character or numbers.

In Carroll County there are some interesting works of the mound-builders. About two miles northeast of the city of Mount Carroll, in the southern margin of Arnold's Grove, three mounds, of rather large size, and somewhat oblong in shape, stand side by side. They were opened a few years ago, but nothing except remains of ashes and charcoal, with a few fragments of bones far gone in decay, were found. On section 32, in the town of Woodland, about six miles west of Mount Carroll, are several groups of mounds. Most of them are the small, common, round mounds. But one group is an exception to this rule. Some of these seem to be unfinished works, some are circular in form, some have a simple depression in the middle, and some are the common round mounds. Ashes and burnt bones were found a few years ago by digging into a few of them. The jaw-bone and teeth of a skeleton were exhumed at the same time, but these evidently belonged to a later time. There is an old tradition coming down from the later Indian tribes which once dwelt here that these were cremation mounds. The internal evidences found by digging them open would seem to confirm this tradition.

About one and a half miles west of Mount Carroll, in a valley made by Carroll Creek, and walled in by high rocks, is a spot of ground filled with fragmentary relics. The waters of the creek caused a part of the bank to cave in, and thus the deposit was first brought to light. By excavating back from the edge of the fallen mass, at the depth of from one to two feet, pieces of pottery quite artistic in design, arrow-heads of a light-colored chert and hard enough to cut letters on glass, prongs of deer's antlers evidently used as some sort of implements, bones of animals in a fair state of preservation, abundant flint chips, and charcoal and burnt stones in great quantities, were found inclosed in a black alluvial deposit. This was evidently a favorite camping ground, and the refuse of the kitchen lies buried over a large space of ground.

In the numerous mounds that might be referred to but one more group will be noticed. These are called "The Mounds" pre-eminently. There are six or seven of them, looking like large blunt-topped hay-stacks in the distance. They are located in the western verge of a high sand prairie, about two miles northwest of the village of Thomson, and can be seen for miles from the north, east, or south. On the west the alluvial flood plain of the Mississippi River is about a mile and a half wide, and is covered by a dense growth of heavy timber. A running slough, a part of the river, washes this steep sand ridge on the west, and passes close to the base of these mounds. Being situated midway between Savanna and Fulton, they are striking objects in the landscape. A rude stone altar was found in one of them a few years ago, but nothing satisfactory can be learned about the relics said to have been inclosed in it.

A pipe, shaped like an eagle—one of the real mound-builders' bird-shaped pipes—was taken from the stone inclosure at the time the excavation was made. Its workmanship was perfect, and its shape artistic in a high degree.

On section 7, in the town of York, just north of the residence of Mr. John Cole, is a most remarkable deposit of flint chippings. They were found on the top of a high sand ridge. A broad expanse of swamp land, formerly covered with water, and an old bed of the Mississippi River, runs up to the base of this sand ridge on the east. On the west the sandy plain recedes and becomes lower. In the first settlement of the country this sand plain and ridge were covered with a sward, which held the sand permanently. Now the pasturage of cattle and cultivation have destroyed this, and many acres are now a naked yellow sand, resting on a harder, sandy subsoil. The winds keep wearing and digging off this sand, and piling it about in other places—sometimes covering neighboring fences; sometimes digging the very posts out of the ground.

All over this sand ridge, for a space a mile long and half a mile wide, flint chippings are being exposed. In some places they occur in masses of a peck or half a bushel; in other places they whiten the ground for yards in extent. The material is a cream-colored chert, breaking with

a smooth, conchoidal fracture. It was all brought there, as no stone is found *in situ* in the whole ridge.

Here was a great manufactory of arrow-heads, and other flint implements. Pieces of arrow-heads, and fragments of the flint in all stages of manufacture, strew the ground. Perfect arrow-heads are sometimes found in clusters. Twenty-six were recently picked up in one nest, rough, but well-nigh finished. Two copper implements, and one of sandstone, evidently used for polishing stone axes, were also picked up.

In Whiteside County, just above the city of Sterling, on a high tableland overlooking Rock River, and on the north bank of the same, is a large group of these mounds. They now form a part of the fine cemetery grounds of that city. Along the south banks of the river below Sterling are a number of quite large mounds, at considerable distances apart. Most of these Sterling mounds are the common round ones. Some of the largest are oblong in form. Many have been partially excavated, and some trinkets and charcoal and ashes observed in them.

At Portland and about Prophetstown similar mounds also exist. On Elkhorn Creek, on the farms of Dr. Pennington and Mr. Dinsmore, some small round ones were noticed.

At Cordova and New Albany, near the banks of the Mississippi River, some large mounds may be seen. At the latter place, Mr. Tyler McWhorter, in the summer of 1872, had a tunnel carried through one of them. This one was 60 feet in diameter at the base and about 12 feet high. In it was found a rude stone inclosure. Portions of skeletons had been placed here, seemingly in detached parts. The structure seemed to belong to the more recent works of the mound-builders.

But it is useless to enumerate further the localities where these mounds may be seen. In almost every picturesque spot they were built; and doubtless they exist in hundreds in this county, as they do in those surrounding it. A village of mounds also exists below Sterling on the north side of Rock River, of large size.

Mercer County contains probably something over one thousand mounds, mostly located over the western third of the county. The eastern part of the county has a few scattered ones of the same general character. Most of these mounds seem to be of very ancient date—they are much flattened by the wear of time, only rising a few feet above the general level. But there are a few mounds on the bottom-lands under the bluffs of more recent date. They have steep declivities, and rise 8 or 10 feet in height. These have yielded well-preserved skeletons; but the more ancient have disclosed to the spade of the excavator no well-preserved bones or implements—only beds of ashes with some charcoal and stones, and, in some of the older, human remains in a state of decay.

In Iowa, opposite to the county of Mercer, and near the Mississippi River, is a high bluff range, on the top of which, facing the town of New Boston, is the old half-forsaken village of Black Hawk. Here are seven or eight mounds, on the brow of the hill, which are the largest

found in this part of the West. They rise twelve or fifteen feet above the general level, and are four or five rods across the base. One of them, on being opened, yielded numerous bones in partial decay; also, pottery, flint implements, and flint chippings.

On the high level plain immediately back of the mounds was formerly an old line of embankment, that contained five or six acres. The ground has been under the plow for many years, and the embankment is now almost gone. But pieces of pottery, flint implements, and numerous chips are yet picked up, and at one time the manufacture of these was evidently carried on here extensively. The pottery seems to have been made of a mixture of river-mud and decayed clam-shells. In short, it was made of lime mortar, and is different from that found in other localities in this part of the country. Pieces of clay pottery are also found about the Black Hawk mounds.

What are called the New Boston shell-heaps are found in this county. They are on a high, sandy river-bank, one-half mile below the town of that name. They are constantly exposed by the sliding down of the bank, and will in time disappear. Each one seems to have contained many tons of shells, mostly in a state of decay. Enough can be seen to determine that they are of the same species as those now existing in the river. The following species are supposed to have been identified: *Unio tuberculatus*, *U. metanever*, *U. plicatus*, *U. asperamus*, *U. anadontoides*. These heaps were formerly some rods from the river. In proximity to them were formerly found old fire-beds of burnt stone, with broken pottery, mostly of burned or baked clay, but occasionally of the pounded-shell mixture, some flint implements, numerous flint chips, &c. These heaps seem to be the kitchen refuse of the mound-builders.

I have referred to this section somewhat in detail, because it is the southwest corner of the tract of country mentioned in this article, and because it illustrates very well the character of the works and remains in the counties lying north of it, contiguous to the Mississippi River.

It would be useless to occupy further space with an enumeration of the mounds of this section. In the counties adjoining those named, they exist almost as thickly as in the latter; but none of them possess, so far as now known, any special or peculiar interest.

WEAPONS AND IMPLEMENTS.

Copper relics.—This region abounds in interesting relics of the true mound-builders. Drift copper is found often. The writer has a bowlder weighing 15 pounds, picked up in a ravine among some small bowlders near Mt. Carroll. Implements of copper are rather scarce, two having come under the immediate observation of the writer. The first was the Sterling copper knife, figured in Foster's Prehistoric Races, and also in the Transactions of the Chicago Academy of Natural Sciences. The cut in the former has no resemblance whatever to the original; while that in the latter is too long for the width. At the time the knife was

found, I was disposed to associate it with the bone of a mastodon found in a similar position higher up the river; but I am now satisfied it is a relic from the mounds which abound in its neighborhood. It was found some six feet below the surface of the soil, in the cut made by a little ravine in the bank of Rock River. It stuck out of the bank when first seen, and was imbedded in a material composed of black diluvial or river-drift, filled with pieces of chert and river gravel. The knife is of pure copper, made, I think, by hammering, and resembles in form one of our long, heavy knives. The broad end has a hole for a rivet, and has the edges turned over for about two inches, making a socket for the handle. The blade is exactly $10\frac{3}{4}$ inches long, an inch and a half wide at the widest part; tapers gradually on both sides—a little more on the cutting edge—to a blunt point. The shape is modern; but the attachment of the handle is of the age of the Lake Superior copper-mining, and the veined appearance denotes an age equal to the older relics of the mound-builders.

The next relic is an ax or hatchet, found half-way between Dixon and Sterling, on the north bank of Rock River, on the farm of a Mr. Lawrence. The locality is one of the most charming, and abounds in relics, such as arrow-points and stone axes. This relic is also of copper, evidently hammered into its present graceful shape. Several surface cracks made by the folding of the metal are to be seen. It is $6\frac{1}{2}$ inches long, $3\frac{1}{8}$ inches wide at the cutting edge, $1\frac{5}{8}$ inches wide at the hammer end, and about one-fourth of an inch thick. There are slight traces of wear on one side, as if made by the friction of a handle. The hatchet resembles a tomahawk, and is a fine specimen of the copper relics of this region. It is in the possession of the writer, but belongs to the collection of Dr. Oliver Everett, of Dixon. Relics of stone pipes are not very abundant. Occasionally one is found made of clay or stone.

In a collection of two hundred arrow-points belonging to the writer, can be selected all the typical shapes given by Sir William Wilde; with all the modifications figured by Foster, including those supposed to be reamers or borers by some of the collectors. A group of arrow-point figures, taken from Lubbock's Prehistoric Times; Evans' Ancient Implements, &c., of Great Britain; or Squier & Davis's Ancient Monuments, &c., will greatly resemble the originals in almost any cabinet in the Northwest. The same is true of spear-heads, and flint-chippings. Flame-colored chert, dark hornstone, and a whitish chert or flint, were the materials commonly used in their manufacture. The writer has picked up very perfectly shaped flint implements, which must have been used for knives and scrapers.

Stone hatchets, axes, and skinning-stones are quite plentiful. The finest in the writer's collection was plowed up among the Kishwaukee mounds. It is of spotted polished granite. A very perfect and artistic tomahawk of stone, of small size, is in the collection of Dr. Everett, at Dixon. The Hanover mounds have furnished a ten-pound ax of very per-

fect shape; but the largest one in this section is in Dr. Everett's collection. It weighs one ounce over 15 pounds; is of dark color; the shape is artistic; the external boundary lines are all graceful curves. Only a giant could have wielded it.

Among these relics of stone the writer has one of unusual shape and appearance; it is somewhat like the section of a circle; thick along the straight edge; and tapering from the top to the circular edge. It was found in a mound, near the north line of the State.

Gorgets, or parallelogram-shaped stones, with two holes drilled through them, are often picked up. The finest one in the writer's collection is of the red-pipe-stone material. A small one in Dr. Everett's collection has but one hole through the end.

Weapons of the size and shape of a goose-egg, with narrow creases round the middle, clubs and hammers undoubtedly, are not rare. In Dr. Everett's collection is a large plummet-shaped implement, with a sort of neck on the smaller end. As a slung-shot it would have proved a formidable weapon.

A very perfect-shaped plummet, made from what seems to be hematite iron ore is in the writer's cabinet. It lacks the usual crease around the small end. One discoidal stone, of spotted greenstone, was picked up in this region, the only one found, so far as I know.

A flint hoe and flint chisel or gouge, from the collection of Dr. J. S. Lowe, in Hanover, are objects of great interest.

Pottery.—Some very perfect specimens of pottery have been found and preserved. The writer has three different styles in his cabinet. Some of the fragments are large enough to show the graceful curves of the vessels before they were broken. The specimens taken from the mounds are of more graceful shape, better and smoother material, and superior hardness, to the later and ruder work of the Indians.

Beads.—Several strings of beads have been taken from the Hanover mounds. These are circular and flat, with a hole in the center; and some of them are artistic in shape. Hanover is the only place where they have been found in this locality, so far as the writer knows.

ANTIQUITIES OF MASON COUNTY, ILLINOIS.

By J. Cochrane, *of Havana, Ill.*

There are five interesting mounds in this vicinity, varying in height from 20 to 40 feet. The two highest are built adjoining each other on the bank of the Illinois River, two others are three miles below them, also on the east bank of the Illinois River, and about ten rods apart; the fifth one is on the bluffs of Illinois River bottoms, west side, and about six miles distant, but in full view of the former ones.

One is of gravelly soil (none of which exists in proximity to it) and the others of loam. No excavations are perceptible in the vicinity

from which the loam could have been taken in such quantity. Many small mounds are situated near by. No excavations or investigations have ever been made.

ANCIENT EARTHWORKS OF ASHLAND COUNTY, OHIO.

By George W. Hill, M. D., *of Ashland, Ohio.*

Evidence of the existence of a race somewhat advanced in the arts of military defense, anterior to the appearance of the Caucasian, is found in almost every part of this county. Mounds and intrenchments in all the great valleys and commanding points are very numerous. The principal streams along which the earthworks are found are the Muddy, the Jerome, the Black and Clear Forks of the Mohican.

Tyler's Fort.—On section 24, now in Wayne County, a short distance below the junction, upon the heights northeast of Tylertown, and east of the stream, is an ancient intrenchment. It overlooks the valley, which here is about one and a half miles wide, and affords an extended view up and down the Mohican. The work is situated on an elevated spur of the ridge, on the lands of Benjamin Tyler; is circular in form, and contains about three acres. When Mr. Tyler took possession in 1814, he found the work destitute of grown timber. The ridge, in and about the intrenchment, had the appearance of having been often burned over. He found the embankment about 4 feet high and about 10 feet in diameter at the base, and completely covered with hazel-bush, about as high as his head. He states that he stood in the center of the work, and could overlook the Mohican Valley for many miles. The work is now covered by a growth of thrifty young white-oak, ranging from 50 to 70 feet in height, and 10 to 15 inches in diameter. Contrary to the general rule, there was no spring in the immediate vicinity of this earthwork.

Ramsey's Fort.—Ascending the Muddy Fork, about 15 miles, we find another intrenchment upon the lands of John Ramsey, on the southwest quarter of section 28, in Jackson Township. The valley of the stream the entire distance is very fertile, and was once a favorite resort of the Delawares. This work is situated on the western side of an elevated ridge, overlooking the valley. The eastern line of the intrenchment reaches the summit facing the valley. The work is quadrangular, and estimated to contain a fraction over two acres. When first discovered the embankment was about 3 feet in height, and from 8 to 10 in diameter at the base. The timber within the fort was equal in size to that of the forest around it, and was of the same character. The area of the fort has been cultivated about twenty-five years, and the embankment is nearly obliterated by the plow. While plowing within the fort, a highly-polished stone hammer was found, five inches long, two inches at the base, and one and one-half inches at the point, encircled in the middle by a

groove. The ravines in the vicinity contained water sufficient to supply the wants of the fort if beleaguered by an enemy.

Two mounds were found in the north part of Perry Township, about one mile from the fort. They were about 30 feet apart, and occupied level ground near a brook. The larger one was about 5 feet high and 25 feet in diameter at the base. The smaller one was probably 12 feet in diameter at the base and 3½ feet high. William Hamilton destroyed the larger one in digging a cellar; and about 4 feet below the natural surface found a triangular wooden post and three human skeletons, one of unusual size, imbedded in sand. On exposure the smaller ones dissolved.

Metcalf's Fort.—By returning to the Jerome Fork, and ascending that stream about one and a half miles, we approach a fort on the lands of the late William Metcalf, south of the stream, on an elevated plateau, facing the valley on section 21. It was circular in form, and contained about three acres. It was near a spring. When first discovered in the forest, in 1812, the embankments were about 4 feet in height, and the base about 10 feet in diameter. Large trees grew in and upon the work. It commanded an extensive view. The fort at Tyler's, some four miles down the stream, could be easily seen by the naked eye. By the means of assault, probably used by the race that then inhabited these valleys, it would have been difficult to capture it.

Winbigler's Fort.—On an elevated point, two and a half miles north, and across the Jerome Fork, was another fort, on the lands of Henry Winbigler, on the northeast quarter of section 9. It contained about four acres of land, was circular in form, and was much more easily defended than Metcalf's, because the ground around it was steep and more difficult of ascent. The embankments were also somewhat higher than the former work, and 10 feet thick at the base. When first discovered it was covered with large timber—a sort of ridge-oak of slow growth, and must have been abandoned for a long series of years. It had a gate-way looking to the north and one to the south, and was near an excellent spring. From this fort a good view of Metcalf's was had. By the use of torches or other signals, the Tyler Fort could have been alarmed at the same time. Nearly due west of this fort, on section 13 in Vermillion Township, is a large mound which was used as a burial site by the Mohegans and Delawares, but was doubtless erected as a signal point by the same race that constructed the forts. West of it about four miles, on section 14, and near the town of Hayesville, is another large mound at the head of a valley reaching the Mohican. It was also most likely used as a signal point.

Gamble's Fort.—Continuing up the Jerome Fork, which rises in the summit, in the north center of the county, is found a beautiful valley, from three to six miles wide, through which that stream meanders, fed by numerous smaller ones on either side. As we approach Ashland, an elevated point of land on the north of the town, on section 8, southwest

quarter, is seen overlooking the whole surrounding country for a distance of from four to seven miles. This work is above the town, and there is a gradual descent from it in all directions. It is a strong military position. A circular embankment, 2,145 feet in length, containing an area of 8¼ acres, surrounded the brow of the hill. When the late Henry Gamble entered upon his land in 1815, the fort was covered by large trees, such as were found in the forest of the neighborhood. The embankments were very nearly 4 feet high in the center, and 10 or 11 feet wide at the base. The work must have required a considerable body of men a long time to construct it. It had a gate-way at the southwest side, facing a deep ravine; and near the gate a very excellent spring. In taking the dimensions of the fort, I was assisted by Col. George W. Urie and Maj. Richard P. Fulkerson, who examined the work nearly fifty years ago, when much of the large timber was standing. The Atlantic and Great Western Railway passes down the ravine just south of the fort, and the spring now supplies the water-tank. The embankments have been plowed over for nearly fifty years, and exhibit but slight traces of their outlines.

In looking down the valley some two miles, a large mound can be seen, which has recently been opened and found to contain human bones, charcoal, and wood, clearly evincing the presence of fire. The mound is situated on the northeast part of section 9, and is composed of sand and drift. The excavation from which it was taken, about one hundred yards away, can be plainly seen. On section 3, in a northeast direction from the above mound, about a quarter of a mile distant, near a fine spring, stood another small mound, which contained human bones, a few arrow-heads, and one or two stone axes and fleshers. These were turned up by the plow. The site of the mound is now obliterated. Other small mounds have been found in Montgomery Township, the contents being similar to the ones described. Four miles northeast of the Gamble Fort, on section 28, in Orange Township, is found the Norris Mound, near the village of Orange. It has been examined and found to contain human bones, large quantities of red and yellow ocher, charcoal, a few shells, and a pure copper needle seven inches long, with a well-tempered point. If the forest were removed this mound could be plainly seen from the fort. It was evidently a burial site. The presence of charcoal, and the oily condition of the hard-pan, ocher, and sand, would suggest that vast quantities of animal oil had been used in its sacrificial ceremonies. It may have been a signal point also. Large trees grew around and upon this mound, its height being about 5 feet, and diameter 30.

About thirty-five years since, while some persons were engaged in cutting a bluff on the bank of the creek east of the residence of the late Patrick Murray, for the purpose of improving the railroad alluded to, a number of human skeletons were unearthed. The bones were in a good state of preservation.

In the year 1850, in digging a well, Isaac Stull, near his residence, half a mile south of the village of Orange, about 5 feet below the surface, came upon an earthern vessel that would hold, perhaps, about two gallons. Before discovering this relic he unfortunately stepped upon and broke it. It was found mouth upward, and resembled in many respects a two-gallon crock. The rim around the top was artistic, and intended to aid in lifting the vessel. It was formed of a bluish earth, and seemed to have been subjected to heat. It was ornamented all over the exterior by finely pulverized white flint, somewhat resembling rice-grains, which adhered firmly to it. A short time afterward, in plowing in a field northwest of his house, Mr. Stull turned up a fragment of the same kind of vessel, as large as his hand.

In the fall of 1872, Harvey Roberts, residing a short distance west of the Stull farm, on an elevation just north of the creek, while engaged in excavating for the foundation of a building, came upon two human skeletons, about 3 feet beneath the surface, in a sitting posture, in a good state of preservation. These remains were undoubtedly those of Wyandots who had died during their annual residence and hunting excursions along the Mohican, over sixty years ago. Another old Indian cemetery was found on the premises of Jacob Young, about half a mile southeast of Mr. Roberts's, and many of the graves being very shallow, were exposed in his garden and on the bank of the creek. Most of the skeletons on the lands of Mr. Young, we believe, were buried in a horizontal position. We do not see the precise reason for this difference. It may be that the parties found by Mr. Roberts may have been chiefs or members of another tribe.

Sprott's Hill.—On the northeast quarter of section 35, in Clear Creek Township, and about two and a half miles northwest of Gamble's Fort, is Sprott's Hill. This hill is about 90 feet high, and contains, at its base, an area of about five acres. It is composed of alluvium, mixed with gravel and rounded bowlders. The top is about 60 by 90 feet, and nearly flat. Upon this two mounds were erected, each about 25 feet in diameter and 4 or 5 feet high. When Thomas Sprott settled there, some fifty years since, large trees grew upon and about these mounds. They were about 30 feet apart. From them a view of the Gamble Fort and the mound at Orange can be had.

In examining the south mound thirty years ago, Thomas Sprott and his brother came upon a sort of stone coffin, constructed of flat stones set on the edges, which contained the skeletons of six or eight Indians, neatly cleaned and packed, in a good state of preservation. On the flat stones, constituting the lid of the coffin, more than a peck of red vermilion was found. These relics were replaced by Mr. Sprott.

About one and a half miles northwest of the Sprott Mound, on section 26, is

Bryte's Fort.—This work is quadrangular in shape. Its longest sides

face the east and west, and are very nearly 500 feet each in length, while the north and south ends are each about 250 feet long, making the whole length of the embankment about 1,500 feet. Near the southwest corner was a gate-way leading to a very fine spring, four or five rods distant. A deep ravine encircles the west side and south end of the work, while there is a gradual descent from the north end and eastern side, showing that it was erected for defensive purposes. The view from the fort in all directions is very fine, and takes in an area of four or five miles. The Orange Mound and those of Sprott's Hill were plainly discernible. When Mr. John Bryte commenced to clear his farm, fifty-four years ago, he found large oak trees and other timber growing on the embankment, and often walked upon it in hunting squirrels. When he first saw it the walls were between 3 and 4 feet high, and perhaps 10 or 11 wide at the base. He has been cultivating the fort for nearly fifty years, and the embankment is nearly obliterated. For defensive purposes, the site was a good one. The water of the adjoining spring would supply a large army. It is situated on the summit where the brooks divide to flow north to Lake Erie and south to the White Woman, the Muskingum, and the Ohio.

Many stone axes, fleshers, arrow-heads, polished and perforated stones, and pipes have been found in the vicinity of the foregoing work.

Shambaugh's Fort.—Returning to the south end of the county, we ascend the Black Fork of the Mohican. At the farm of Lewis Oliver, and one or two points below, were found mounds of 5 or 6 feet in height and about 30 feet in diameter at the base. A little southwest of Perrysville, on the road leading to Newville, on the summit above the village, was a mound overlooking the valley the size of the ones described.

Passing up the stream to near the old Indian village of Greentown, to the lands of Mr. John Shambaugh, on the north side of the stream, on section 18, we find another circular fort, containing very nearly two acres, with a gate-way looking to the west. In the center was a mound, about 4 feet high, which had probably been an altar or lookout. When first discovered, the embankment was about 3½ feet high and 10 wide at the base. It is difficult to conjecture for what purpose the work was constructed, as it was situated on the bottom, fully a quarter of a mile from the elevated lands on either side of the stream. A small brook flowed by it, from which, no doubt, water was obtained. Timber—such as oak, hickory, and elm—grew upon and within the work, the larger trees being over 3 feet in diameter. The lands along the streams are very fertile, and the site of the fortification having been plowed over for half a century, the embankments are merely traceable.

The Parr Fort.—About one mile distant from the work alluded to, on section 19, is found what is known as the Parr Fort. It is also a circular work, the embankment, when first discovered by the pioneers, being about 7 feet high, and 12 or 14 in diameter at the base. It inclosed an

area of about three acres, and had a gate-way at the west. Very near it, on the east side, stood a large mound, from which copper beads and stone implements have been taken.

I am informed by Dr. J. P. Henderson, of Newville, that this mound was opened about fifty years ago. In it were found human bones, charcoal, decayed wood, a stone pipe, the stem of which was wrapped with copper wire, and a copper wedge. The mound was of a peculiar structure. It was built of large flat stones in a circular form, like a shot-tower, and filled up and around with earth, and was a cone in appearance. Many stone axes, stone fleshers, and polished stone plates have been found in the vicinity of these works.

Darling's Fort.—About two and a half miles south of Parr's fort, near Saint John's church, on the north bank of the Clear Fork of the Mohican, may be seen another defensive work. It is circular, and contains an area of nearly 3 acres. It had embankments from the gate on the south side (as I am informed), leading down to the bank of the stream. When first discovered it was covered with large timber, and the embankment was over 3 feet high. It commands a full view of the valley for many miles, and was doubtless used as a defensive work. Many very choice stone relics have been plowed up along the valley by farmers, and are now in the cabinet of Dr. James P. Henderson, of Newville.

We find no other remains until we reach the village of Mifflin. On level land a little northwest of this village is a large mound. The top is slightly flattened, and was, no doubt, used as a burial spot by the Delawares. It has not been excavated and its contents are only a matter of conjecture. Many stone axes, some beads, flint arrow-heads, and pick-shaped implements of stone, highly finished, have been plowed up by the farmers all along the valley of the Black Fork.

There are, perhaps, twenty or thirty smaller mounds scattered over the country, to which my attention has not been given. The mounds of this county are invariably truncated, and none exceed 10 feet in height. I am inclined to the opinion that many of the smaller ones were the center of an encampment, and were erected for sacrificial purposes. Such a mound existed in the center of the council-house of Greentown. The venison and bear-meat for their great feasts was boiled in large copper kettles upon the mound. This may account for the charcoal, ashes, and charred bones so frequently found in small flat mounds. I have reason to believe, also, the tent or wigwam of the ruling chief was sometimes placed on a central mound of similar structure.

Stone implements.—Several classes of implements are found in great numbers within this county. They seem to have been scattered broadcast over the hills and valleys. One class consists of highly-polished stone pestles, stone axes, weighing from six or eight ounces to five or six pounds, stone fleshers, stone implements, pick-shaped, with a neatly-drilled hole in the middle, stone beads, and flat variegated stones from

one to two inches wide, six or seven long, and half an inch thick, with rounded ends, highly polished, and generally with a neatly-drilled hole in the center, have been found in and about these ancient works.

Another class, of more recent date, consists of thousands of flint arrow-heads, from a half inch to seven inches in length. These were unquestionably made by the modern tribes that overspread Northern Ohio, and most of the material was procured from the ridges in Licking County. One such nest was plowed up in Sullivan Township, three years since, by Mr. W. S. Riggs, containing 201 pear-shaped arrow-heads, neatly finished and of an unusual style, having no notch for fastening them to the shaft, and had the appearance of being intended for cutting.

FLINT IMPLEMENTS IN HOLMES COUNTY, OHIO.

By H. B. Case, *of Loudonville, Ohio.*

An interesting "find" of flint implements of the leaf-shaped pattern was discovered in the summer of 1870 on the farm of Daniel Kick, about half a mile north of the Lake Fork of Mohican River, in Washington Township, Holmes County, Ohio. They were found in a pond or basin-like depression formed in the glacial drift or river gravel which is found in this vicinity. The pond has no outlet, as the rim of the basin is 20 feet high. In order to collect the water, which, during most seasons, covers the bottom of the pond, a ditch 4 feet deep was dug through it. Near the bottom of the ditch were found the remains of an old oak log lying across the cutting, and beside the log were found ninety-six flint implements, all leaf-shaped, and of sizes from 2¼ to 5½ inches in length. They were colored by red oxide of iron, which adhered very tenaciously to the flint, showing that a quantity of this material had been deposited with them. This pond, in seasons of great drought, becomes dry, but has not been so for several years. Were these implements buried in the pond by the owner, or were they placed beside the log and covered by the slow accumulations of the alluvial deposits of centuries? The pond never having had an outlet since the deposition of the glacial drift, and the flints being found within a foot of the bottom of the four feet of alluvial deposit, would indicate, if deposited upon the surface, an antiquity of three-fourths of the post-glacial period, assuming that the alluvium was laid down uniformly, and that the flints were placed beside the log and had not been buried, and had not sunk to their place from higher up in the mud. These implements are now in the collection of the writer, who has furnished specimens of the same to the National Museum at Washington.*

* The implements were, in all probability, intentionally buried, forming a deposit or "cache."

MOUND IN TRUMBULL COUNTY, OHIO.

By F. Miller, *of West Farmington, Ohio.*

The mound referred to is situated about a mile north from the village of West Farmington, Ohio, on the land of Mr. Belden. Its elevation above Swine Creek, flowing near by, is about 70 feet, and its height is supposed to have been some 30 feet above the level of the land. It has been much reduced in circumference by the plow. Two years ago a gentleman dug three holes in the mound, in one of which he found a square piece of lead; in another, some red paint, and a round stone in the form of a human head, and some bones. In the third, and central excavation, he found two skulls; but they were so much decayed as to crumble on exposure. The jaws and teeth of one of the specimens remained perfect. The bodies originally were laid in circular tiers, with their heads in the center and the feet outward. Above and below each there was placed a flat stone, which must have been brought at least six or seven miles from here, as none of that kind are found in this vicinity. How many tiers of bodies there were I could not learn, as there was no note made of it. In the upper part of the mound a skeleton of large size was discovered. Flint tools were also discovered with the bodies.

The father of the present owner settled here about sixty years ago and on his arrival found beech-trees over 2 feet in diameter surrounding the mound, several of which were hollow.

ANTIQUITIES OF HANCOCK COUNTY, KENTUCKY.

By Joseph Friel, *of Cloverport, Ky.*

About a mile north of Bennettsville, Hancock County, Kentucky, is a range of hills, at the foot of which runs Allen Cave Creek. These hills are capped by high sandstone ledges, which have been so eroded in past ages as to leave overhanging shelters at several points; some of these are of considerable size; one, particularly, seems to have been occupied by man for a long period, but now serves only as a shelter for hogs. The cavern is open toward the south, the overhanging roof protecting the space below from any exposure to the elements from above, while an immense rock which has fallen down forms a partial wall directly in front, between which and the rear wall of the cavern the deposit containing prehistoric remains is found. This deposit consists of rich black loam, wood ashes, and decomposed vegetable matter. The deposit is 27 by 12 feet, and from 12 to 22 inches deep. I found large quantities of flint chips and fragments of arrow-heads scattered all over the surface of the deposit. On digging down I found bones, flint-chips, wood ashes, charcoal, burnt

sand-rocks, fragments of rude pottery, pieces of decomposed wood, and frequently pieces of muscle shells. I found signs of fire mostly in the center of the cave, while fragments of pottery and bones were more frequently met near the outer edge. A small piece of a cocoanut shell was discovered near the bottom of the deposit. This proves that the cave-dwellers of Kentucky carried on trade to some extent with their southern neighbors. About three hundred yards farther down the valley, and on the opposite side, at a corresponding elevation, is an underground cavern which runs under the hill to a considerable distance. In this cave I hoped to find the skeletons of the ancient cave-dwellers, but I was mistaken. After a diligent examination of every part I discovered nothing but the skull of an animal. In one corner near the mouth of the cave I found a number of burnt sand-rocks, but could discover no other signs of fire or human habitation. I find a great many arrow-heads and flint chips scattered all over this country, and also numbers of rough sandstones with cavities in one side.

Recently I visited the mounds of Indian Hill, located on the farm of Mr. James Sanders, about three and a half miles north of Pellsville, Hancock County, Kentucky. Indian Hill is about 150 feet in height, and on the summit of it are three mounds built entirely of sandstone, which must have been conveyed a distance of at least 250 yards up the steep side of the hill. The mounds are 25 feet in diameter at the base, and were originally 12 feet in height, 15 feet apart, and in a straight line with the ridge, of the hill, which runs in a direction northeast by east. The average weight of the stones used in constructing these mounds is about 65 pounds, but many of them will weigh 100 pounds. The mounds were perfectly solid, having no cavity in the interior whatever, neither were used as sepulchres, for the parties who opened them some years ago state that they found no traces of human remains. Close to the base of one of the mounds is a white-oak tree which is about 18 or 20 inches in diameter, and probably one hundred and fifteen years of age. This tree bears no mark or hacks, which it doubtless would have received and yet exhibit, if the Indians who occupied this country one hundred years ago were in any way connected with these mounds. About 20 feet northeast of the most northerly mound many flint chips may be found, which indicates the place where the mound-builders were in the habit of manufacturing their arrow-heads, spear-heads, &c. Many stone implements occur in the vicinity of these mounds.

ANTIQUITIES OF TENNESSEE.

By W. M. Clark, *of Franklin, Tenn.*

The mounds and cemeteries of Tennessee are situated throughout the whole of the State, but especially in the middle portion. The Indians seem to have preferred a water-course for their habitations, and it is generally the case, that, wherever these remains exist, there are the very

best of our farming lands. There are various kinds of these remains, such as mounds, cemeteries, and fortified camps. There is a singular chain of works extending from the Tennessee River at Florence, Ala., diagonally across the State of Tennessee and resting on the Upper Cumberland River near Monticello, Ky. Whether or not this chain denoted a line of travel for the aborigines, or was accidentally the most thickly populated section of country, I know not. This region, at any rate, is far-famed for its fertile soil, and is, at this time, the most thickly populated section of Tennessee. In the county of Williamson alone, where my investigations principally were made, are four fortified camps, and the builders of these defenses evinced a shrewdness in the selection of location and the manner of improving the natural advantages that we seldom find among the ignorant savages of the present day.

In May, 1875, with a force of hands, I commenced digging in a large mound situated two miles from Franklin, in this county. This mound is located upon a high hill on the farm of Dr. William Reid. The hill is isolated, and commands a view of the country for many miles in every direction. It is 400 feet in circumference, and is surrounded by a level terrace, smooth, and free from stones. The height above the terrace, after ages of settling and attrition, is 20 feet. It is covered by a growth of trees similar to those of the surrounding forest, which has never been cleared. The hill is very rocky, and the wonder to me was where so much soil had been procured. But my wonder ceased after a few hours' digging, for, when I had penetrated the deposit of made-soil on the surface about 18 inches, I came to the material of its construction, which consisted almost wholly of limestone bowlders, gathered from the face of the hill. These stones varied from small, broken pieces to masses which would tax the strength of a large man to carry. About 4 feet from the top, we came to a layer of graves extending across the entire mound. The graves were constructed in the same manner as those found in the cemeteries, hereafter to be described; that is, of two wide parallel slabs, about 2½ feet long for sides, and with the bottom, head, and foot stone of the same material, making, when put together, a box or sarcophagus. Each of these coffins had bones in it, some of women and children together, and others of men. Numerous bones of rodents, and a few of deer, were mixed with the human bones, and were in a much better state of preservation than the latter. In fact, the human bones were very much decayed, and I was able to obtain only a few fragments. The skeletons were laid in the graves with the heads to the east, and the arm and leg bones were alongside of the body. It is probable that the later tribe of Indians used this place as a sepulcher, from the fact that these graves were so near the top of the mound, having, in the other mounds, found the skeletons at or near the center, and at the bottom. The only relics I discovered among these graves were a string of beads, which were lying with the cervical vertebra of the skeleton of a woman. These beads are made of chalk,* and have a polish when not eroded by lying in con-

* Probably of shell, which, when decomposed, has the appearance of chalk.

tact with the soil. They are large in the center, gradually tapering each way to the end. There were also some broken fragments of pottery, but no entire vessels. We penetrated the center of this mound until we struck the top of the hill, and it appeared that the builders had made no change in its apex, but simply piled up rocks, with, possibly, some soil, at its summit, the top being slightly truncated.

About two miles to the west is a group of mounds, and a cemetery, and every evidence of a large encampment. Earth-works were also once there, but they have been destroyed by cultivation, being located in a very fertile valley on West Harpeth, and all fully in view of this mound. I am under the impression that this was an advanced outpost for the village, and, as such, was used as a signal station to warn the inhabitants of approaching danger. There was no altar at its bottom, nor any evidence of fire, except just above the graves, where a few ashes were found, caused probably by the signal-fires here lighted. Whether the terrace was made by the subtraction of the soil in the formation of the mound, or by soil carried there, did not appear.

North of this hill and near its base, on a slight elevation, were three small mounds, not more than 20 feet in diameter and about 6 feet high, though their height had been reduced by cultivation. I examined two of them, and found no remains of skeletons or relics, but beneath the level of the surrounding land was a simple pile of stone mixed with ashes. These were evidently altars, and though rudely put up, showed the handiwork of man. We went altogether below the stones, but found nothing. I then removed my party to the farm of Samuel F. Glass, to the encampments above alluded to, about two miles to the west. There is a fine group of mounds, and four of them are in a line from north to south; a large one in the center, flanked on the south by two small ones, and on the north by another, evidently intended to be a large one, but from some interruption never finished. This last was not more than 3 feet high, though 75 feet in diameter. It had been cultivated a great number of years, but showed distinctly its proportions. Being in cultivation at the time of my visit, I did not examine it. The two smaller ones were about 6 feet high and 20 feet in diameter, while the largest was 20 feet high and 400 feet in circumference. They did not stand in a perfect line, but formed the segment of a very large circle, the largest mound forming the lowest part of the curve. I made a section across the large one, carefully noting the work which progressed from either side. I dug east and west two trenches, meeting in the center. This proved very conclusively to have been a sacrificial mound, and though the relics found were indeed few, yet they were of the greatest interest. There were no stones in the mound, it being constructed entirely of soil, not even any clay being visible. It had, 5 feet from the summit, a layer of ashes and baked earth. This layer was conical, as if spread over the top and afterward covered up. The evidence of fire extended about 8 feet over the surface, so that, in the section presented to view, the ashes formed

a curve about 8 feet across. Charred wood was intermixed with the ashes, showing that the earth had been piled on it while yet burning. No fragments of bone were found, as they would surely have been if there had been any burning of animal offerings. These layers of burnt soil and ashes recurred every 5 feet, until we reached the last, which was on a level with the earth, but for 4 feet below the surface the whole seemed baked and interspersed with ashes and charcoal. In this charred mass of earth we came upon the only relics contained in the mound; both are of copper, and were made of unsmelted ore. No. 1 is a face or mask, and is composed of four pieces. The main pieces are beaten together in the center by some instrument of stone, the mark of the blows being distinctly visible. One piece is riveted on each side to represent ears, and the rivets are exceedingly well put in and firmly united. It is oval in shape, 6 inches long and 4 wide, being about as large as the average face of a man. By aid of a sharp tool small dots were made to trace the location of the eyes, eyebrows, nose, and mouth, and a horizontal line beneath the nose shows the place of the nose-stick, which has a pendant on either end, with a bead or other ornament resting on the cheek. At its lower edge, below the chin, are three rivet-holes, by which it was possibly fastened to a wooden or stone body, and then raised upon the altar, with its burnished surface glittering in the sun, an object of pride and admiration to the assembled nation. One side of this mask is eroded, and the whole is heavily coated with the oxide of copper. By its side lay another; it consists of two concave disks, which are connected together by a stem, the whole being shaped like an hour-glass, hollow through its entire length. It was also hammered out of copper ore, and so deftly done that no joints are visible either in the ends or in the stem. The stem is not riveted, but seems continuous, as if it had been cast in one piece; yet the blows of the tool with which it was made are plainly visible. At first I supposed it to have been a spool upon which the Indians wound their thread of sinews; nor could I have guessed its proper use had I not discovered one of a similar kind in an adjacent mound. It would have been a costly spool, for, no doubt, with their mechanical appliances, it was a labor of long duration to fashion one such, and I afterward became convinced that it was an emblem of authority, and was worn around the neck of their priest. Where did they procure the copper? There is none in this country nearer than the mountains of Unaka, 300 miles distant, and the still more remote shores of Lake Superior. The existence of copper implements is so rare in this State, that they must have been indeed precious to the tribe owning them, and may have been buried for safe-keeping. The two smaller mounds were now examined, but, in the one nearest the large one I found nothing, it having been previously opened and examined by Dr. Joseph Jones, of New Orleans. In the farther one, however, I found an oval piece of galena, weighing three pounds—this lay about 4 inches to one side of the other objects—and a piece of a lower

maxillary bone. A man had been buried in this mound, but all that was left of him was some bone-earth, showing where they laid him, and this small fragment of the jaw-bone, preserved by its contact with the copper, it being colored and permeated by the oxide of copper. It is the central piece of the lower jaw, and shows on each side the mental foramina and the absorbed remains of the alveolar processes. Only fragments of the incisors remain. Now, the fact that the skeleton was entirely decayed, excepting this small fragment, plainly indicates its great antiquity; for in all the mounds examined, not only by myself, but by others, where the remains of bones are discovered at all, they are in a good state of preservation, the depth of the sepulcher preserving them from decay. And yet, in the bottom of this mound, never before brought to light, or subjected to the influences of the atmosphere, only this remains; and even that would have long since moldered into dust had it not been in contact with, and almost surrounded by, this piece of copper. Nor was this the only strange thing preserved by this copper, for on the stem of the bobbin was about 18 inches of flax-thread and through its center was a piece of cord. This thread and cord are green from the effect of the copper and still retain some degree of strength. I say it is flax, but of that I am not certain, as I examined it with a pocket microscope only. It certainly is not of animal fiber, but is vegetable. It had evidently been hanging around the neck of the skeleton over which this mound was erected, and, the lower jaw dropping, the mental portion of the bone became naturally wedged in the copper bobbin, and thus it remained until my discovery. The skeleton was that of a very old man. In all my exhumations I have not before found a decayed skeleton, rarely even a missing tooth. The order of loss is well known; first, the molars, then the bicuspids, and finally the incisors. Here all were gone. From these facts I suppose this man to have attained a very great age. From the known veneration of the later races of Indians for the aged, I infer that he was one of their rulers; and the Indians being patriarchal in their form of government, he must have been a priest and a noted person, or no mound would have marked the place of his burial. This, then, is my reason for believing these copper bobbins to have been the symbols of office or authority, and not simply spools upon which to wind their thread. The fragment of thread is coated with some kind of gum, probably asphaltum, and that, no doubt, contributed to its preservation. These few relics were all that was obtained from these mounds, except the piece of galena, before alluded to, which may have served to give weight to the club of some stalwart warrior. Unfortunately the land has been cleared and cultivated so long that most of the graves have been destroyed. Several ledges of rock pass through it, and in every crevice of these ledges bones are deposited. They are also to be found scattered over the ground, where they have not been destroyed by the plow and the elements. Old settlers say that at one time the ground was thickly strewed with them. Near the

center of the great cemetery stands a huge mound, the finest in the country, and one which I was anxious to examine, but was prevented from doing so by the scruples of the owner. I examined some of the graves, however. I found them, as usual, composed of flat stones, set edgewise, with stone bottoms, but no covering except earth. Several pieces of crockery were broken by the carelessness of the assistants. One specimen resembles perfectly a squash, and tends to show that this vegetable at least was familiar to these people. I also obtained a string of beads, and an amulet which resembles the face of a man. Many relics have been taken from these graves, but being considered of little value were neglected until lost or destroyed. There was at one time a large fortified camp which withstood the changes of time, but it has long since yielded to the influence of the plow. Three miles south of Franklin, on a bluff of Big Harpeth River, was another camp, covering twelve acres of land, each end of the inclosing earth-work resting upon the bluff. This camp was surrounded by a wall and ditch, and three mounds were within the inclosure. Three mounds were examined in 1867 by Professor Jones, the result of which I have not been able to procure. I found a few isolated graves there, from which I procured a very perfect vase with ears to it. This vase was lying inverted by the neck of a male skeleton, and there were also some bones of a deer. A pile of rocks near by indicated, as I thought, a grave, but I found it to be an oven, lined at the bottom and sides with baked clay, and covered with flat rocks. It had broken pieces of pottery in it. On the largest of the three mounds, about half-way up the slope, a grave was discovered containing a large skeleton. Piercing the sternum, from the interior, was a small, delicately-made arrow-head, the cause, no doubt, of the death of the buried man.

The most celebrated cemetery, and the one most frequently resorted to by relic-hunters, is at "Old Town," seven miles northwest of Franklin, on the farm of Mrs. Brown. Formerly, like other encampments, it had a wall and ditch surrounding it, but they are gone. There were many graves and mounds scattered over the inclosure. Most of these graves have long since been emptied of their contents, and the mounds, for the most part, have been dug into. However, I obtained some very interesting relics here, among them two beautiful pieces of ivory carved with a precision seldom seen among Indians. They are made from a tusk, probably, of the mastodon. The larger one must have come from the tusk of a monster, for to furnish material for such a gorget it must have been 12 inches in diameter. These gorgets have two holes in the edge, near each other, and they were most probably worn suspended on the breast, and may have been emblems of authority. One of them was in the grave of a giant, for a large man could pass the lower jaw-bone around his face; and the thigh-bone was four inches longer than that of a man six feet two inches high. A piece was fractured off one edge by accident after taking it up. Another string of

beads was procured here. They are made of bone, are quite small, and were lying in the grave of an infant. The dead in this cemetery were all buried with their heads toward the east, and some graves contained the bones of three or four persons. It was quite common to find the bones of children and adults in one grave, though occasionally a grave was occupied by several children. The relics, when there were any, were always found by the side of the skull.

Where they procured the material to make the greenstone axes found among their grave relics I cannot say, as it is a volcanic or igneous rock, and none is found in this State. It is said that a bluff on the Missouri River furnished the neighboring Indians with the material for these and many other implements.

A jar holding about two quarts, and a small pot, were exhumed. In the latter was found a piece of oxide of iron, weighing about two ounces, which shows a worn spot, where it had been scraped by the owners to obtain paint for their bodies. It readily yields a dusky-red color on being moistened. In one of the graves were found five beautiful oblong beads of amber, two inches long, and in the center one-half inch in diameter. They were smoothly bored, and, though showing some cracks, were still entire. Unfortunately, these were stolen. They showed a fine polish, and would have been prized by our ladies very highly. I also saw a bead of the same material raised upon the drill of a well-borer in this town, only differing from the others in the fact that it was round and about the size of a grape. It was accidentally lost by the gentlemen who discovered it. I have a small implement of conglomerate—iron, silica, and pyroxene—so hard that the best file will make no impression upon it, and tapering both ways from about one-third its length. It is difficult to conceive its use, unless by the aid of sharp sand it was used to bore or drill the bowl and stem-hole of their pipes. It fits those openings in both the pipes which I have. I also procured a large number of axes of every size, from the smallest tomahawk to the largest chopping-ax. Flint arrow-heads, harpoon-heads, and spear-heads also are plentiful in my collection, besides many other utensils and implements. On the bluffs of the Big Harpeth many pictures of Indians, deer, buffalo, and bows and arrows are to be seen. These pictures are rudely drawn, but the coloring is as perfect now as when first put on. We have also bone awls, buckhorn handles for knives, &c.

We now have to consider the most interesting relics found with the dead aborigines, viz, the idols; and, as I have before stated, since it is universally conceded that our Indians are the only known savage race which does not worship idols, it is difficult to define the use to which these relics were put by their owners. I have procured four specimens, all of sandstone, except one made of clay and sand and burnt. One of these idols weighs 27½ pounds, and is cut from a solid block of sandstone. It is remarkable for its great resemblance to the idols of

India and China. The workmanship is rude, it is true, but faithful in its details. The legs are only represented to the knees. There is an attempt to show the hair, and at the back of the head there is a knot of hair, with a loop for the suspension of ornaments. This figure does not contain an opening like a pipe, and was evidently only intended as a representation of a man. It was found lying in a grave by the side of a huge skeleton, much taller than the present race of men. The skeleton was in such a state of decay that it could not be preserved. Another idol of sandstone of much ruder workmanship than the former was found here. It weighs eight pounds, and was also taken from a grave. Evidently art was in its earliest stages when this was executed, and it is rather a caricature than a likeness of man. The arms folded on the breast are only outlines traced in the stone, and the features are made in a similar manner. The breasts are larger in proportion than those of the former image, and from their prominence I am inclined to think it was intended for a female. Another figure about the same size and of the same material was found; it unquestionably represents a woman. The features are more distinct, and the arms, instead of being crossed, rest upon the side, with the hands upon the knees. The breasts are well developed, and the spinal column is marked along the entire length of the back. The head-dress is peculiar, the hair being in folds, and divided into three separate parts, with a knot on the top of the head. All these images were taken from graves, though mounds were in their immediate vicinity. I have many other relics of the mound-builders, but these comprise the most important and interesting.

ANTIQUITIES OF NASHVILLE, TENN.

By R. S. Robertson, *of Fort Wayne, Ind.*

On the 27th of August, 1877, during the session of the American Association for the Advancement of Science, in company with Mr. H. U. Rust, of Chicago, and Mr. E. Curtis, of Nashville, I visited a locality famous for its stone graves, or "cist" burials. It is a vast cemetery, situate on a hill-side, about two miles from the State House, beyond Fisk University, the hill being crowned by Fort Zollicoffer, a Confederate earth-work commanding the Cumberland River for a considerable distance. Nearly all the hills and ridges in the vicinity are said to have been occupied and used as cemeteries by the aborigines. A brief search through a corn-field close at hand rewarded us with a number of perfect and broken arrow-points and two pestles, one of which is peculiar from having the upper end flattened like the "fleshers," or "skin-dressing implements." The ground on the face of the hill, where denuded by the action of the weather, is covered with periwinkle shells, and on digging we found them everywhere mixed in large quantities with the

earth filling the graves. The graves, or "cists," do not seem to be laid out according to any regular plan, though many of them are side by side and located close together. We found none, however, in which the same slab was used as a partition between two burials, but those opened were complete in themselves. Of two completely exhumed by us, lying side by side, one had stone slabs lying on the bottom upon which the body had been laid. The sides and ends of the grave were lined with thin limestone slabs, making a complete stone cist, about six feet long and just wide enough for the body to be placed within it, with the arms pressed close to the side. The body had been placed on its back, but the head had fallen a little to the right side; and the pressure of the earth had caused a distortion of the base of the skull in the opposite direction from the point on which the skull rested. Close to the left shoulder a small earthen vase, holding about a gill, was found. It had perforated ears for suspension, and was filled with some carbonized matter. The skeleton of a child, of about two years (as we surmise from the condition of the teeth), lay between or upon the legs of the adult (probably a female), its head between the thighs, and the body extended down along the legs. The earth inside the cist was very compact, and mixed very thoroughly with periwinkle shells. I concluded, from the compactness of the earth within the cist, that it had been heaped up and the slabs laid upon the heap to allow for settling, as no space existed between the covering slabs and the earth beneath.

In the next grave there were no stones forming a bottom to the cist, but the body lay upon the earth. In this case the head had not turned at all, and the distortion by compression was a flattening of the rear of the skull, so that the diameter from front to rear was less than the lateral diameter. No ornaments, tools, or pottery were discovered in this grave, but a flint arrow-head of the blunt pattern was found in the earth above the covering slabs. Another noticeable feature was the fact that part of the covering had fallen in at one side. Had the stone been laid upon the upright slabs forming the sides, it could hardly have fallen in in that manner, but must have broken by the weight of the superincumbent earth. The earth filling the grave, as in the other, was mixed with shells.

These graves are found everywhere about Nashville, and within the city limits. On the ridges close to the Sulphur Spring, the stones inclosing such graves may be seen protruding from the ground, where the earth above has weathered off. Fragments of pottery abound, some of the common sort, and others very thick—about one-half to three-fourths inch—composed of a grayish clay, with large fragments of shells. The vessels of which they were part must have been very large. Traditionally, they are believed to have been used in evaporating salt from the spring. A brief search resulted in finding numerous specimens on the surface and protruding from the sides of the ridges near the surface.

It is said that the saline properties of the spring were more noticeable before the deep bore was made which produced the sulphur water, which is so much patronized. The well is now 300 feet deep.

My main object in presenting these facts is to call attention to the distorted condition of the crania. In my opinion many otherwise acute observers have been misled in their classification of skulls by the appearance of those distorted by pressure.

My experience has led me to believe that many skulls considered abnormal, or as belonging to a race type, are simply distorted by the pressure of the superincumbent earth. To illustrate: If a corpse has been buried in a sandy or otherwise loose earth, with the eyes turned upward, as the soft parts decay, the skull is filled by the earth penetrating or silting down through the sockets so as to present a resistance to pressure, and we may expect to find a skull in the normal condition. If, on the other hand, the earth is hard and not of a quality to penetrate and fill the skull, or if the skull be turned to one side so as to prevent it being filled except by a slow process, we may expect to find the skull distorted, bent as it were, and, so far as my experience goes, the rule is invariable. If the head lay on its side we should have a dolichocephalic, and if upon its back a brachycephalic skull, without any breaking of the bone. If turned to either side, we should have a distorted skull, which belongs to neither class, but might be unwittingly classed as a "type," or as an abnormal development.

ABORIGINAL STRUCTURES IN GEORGIA.

By Charles C. Jones, Jr.

I.

BIRD-SHAPED STONE TUMULI IN PUTNAM COUNTY, GEORGIA.

The existence of curious effigy-mounds in the southern counties of Wisconsin was noted by Mr. Lapham in 1836. Subsequently, Mr. Taylor, Professor Locke, and Messrs. Squier and Davis furnished additional information in regard to the distinctive characteristics of these unusual structures. It was reserved, however, for the Smithsonian Institution, in the seventh volume of its "Contributions," to furnish, from the pen of Mr. Lapham, the most complete account of these interesting remains. They were quite numerous along the great Indian trail or war-path from Lake Michigan, near Milwaukee, to the Mississippi above the Prairie du Chien. Generally representing men, buffaloes, elks, bears, otters, wolves, raccoons, birds, serpents, lizards, turtles, and frogs, in some instances they were supposed to typify inanimate objects, such as bows and arrows, crosses, and tobacco-pipes. While the outlines of not

a few had been seriously impaired, others in a spirited and correct manner declared the objects of their imitation. Constructed of earth, they varied in height from 6 inches to 7 feet. In certain localities the animals were delineated not in relief but in *intaglio*, by excavations and not by elevations.

Two *animal mounds* have been observed in Ohio. On an elevated spur of land near Granville is an earthwork known in the neighborhood as the *Alligator*. Its total length is 250 feet. The head and body, four sprawling legs and a curled tail, were all clearly defined. Across the body it was 40 feet broad, and the length of the legs was 36 feet. Four feet expressed the average height, while at the shoulders the mound attained an elevation of 6 feet. It was manifestly the effort of the primitive workmen to preserve the proportions of the reptile.

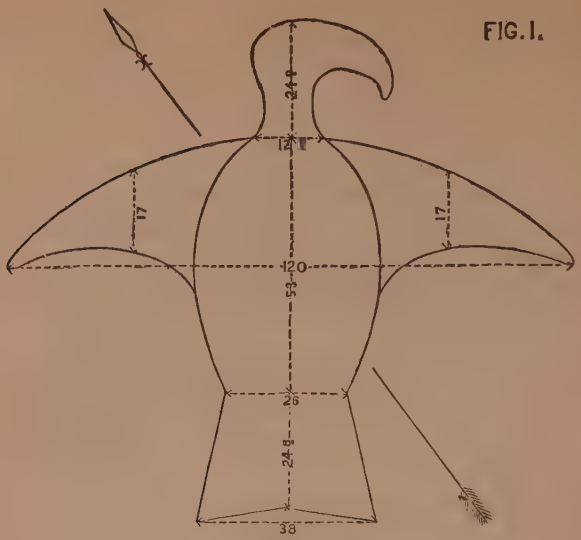
Situated on a ridge rising 150 feet above Brush Creek, in Adams County, is a still more remarkable structure, which, from its configuration, has received the appellation of the *Great Serpent*. "Conforming to the curve of the hill, and occupying its very summit, is the serpent, its head resting near the point and its body winding back for 700 feet in graceful undulations, terminating in a triple coil at the tail." If extended, its entire length would be not less than 1,000 feet. The embankment is upward of 5 feet high, with a base diameter of 30 feet at the center of the body, whence it diminishes somewhat toward the head and tail. "The neck of the serpent is stretched out and slightly curved, and its mouth is opened wide, as if in the act of swallowing or ejecting an oval figure, which rests partially within the distended jaws."

When and by whom these remarkable tumuli were built is not known. The object of their construction is equally a matter of conjecture.

It has been supposed that these animal-shaped mounds existed only in Wisconsin and a few other localities in the West. Our recent observations prove, however, that the primitive dwellers in the South have left similar traces of their constructive skill.

Six miles and a half north of Eatonton, in Putnam County, Georgia, on a plantation owned by the heirs of the late Mr. I. H. Scott, may now be seen a bird-shaped mound of definite configuration. Located in the midst of a beautiful wood, and crowning a high ridge near the headwaters of Little Glady Creek, it is composed entirely of bowlders of white quartz rock, gathered from the adjacent territory. Most of these bowlders are of such size that they could have been transported by a single individual. For the removal of others two or three persons would have been requisite. These bowlders were carefully piled one above another, the interstices being filled with smaller fragments of milky quartz. Into the composition of the structure enters neither earth nor clay.

FIG. I.



Scale 40 feet to 1 inch.

Bird-shaped stone mound in Putnam County, Georgia.

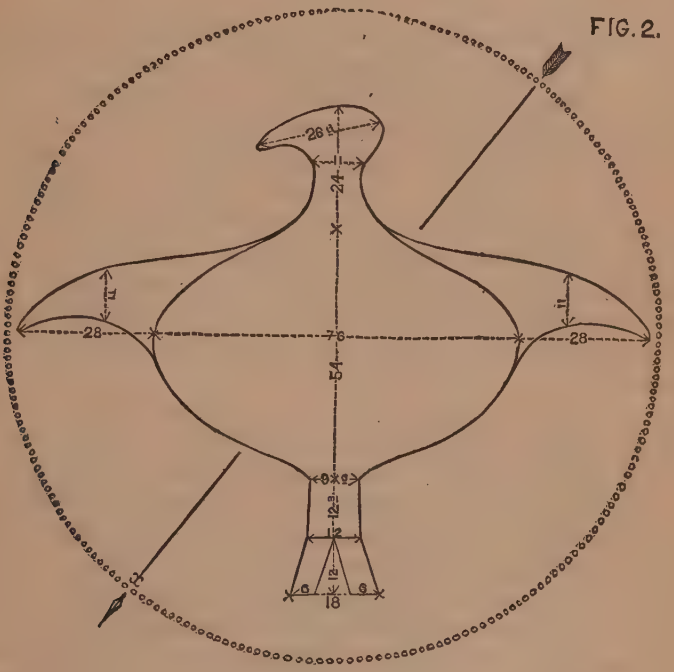
This stone mound represents an eagle lying upon its back, with extended wings. (See Fig. 1.) The head is turned toward the east. In the construction of this tumulus respect was had to the object imitated; the height of the tumulus at the breast of the bird being between 7 and 8 feet, its altitude thence decreasing toward the head and beak, where it is not more than 2½ feet high, and also toward the extremity of the wings and tail, where it has an elevation of scarcely 2 feet The beak is decidedly aquiline, and the tail is indented. Measured from the top of the head to the extremity of the tail this structure is 102 feet long. From tip to tip of the wings, measured across the body, we have a distance of 120 feet. The greatest expanse of tail is 38 feet, the same as the lateral diameter of the body. The proportions of the head, neck, wings, and tail are cleverly preserved. That this tumulus was designed to typify an eagle, we think may be affirmed with some degree of confidence, and that it possesses unusual attractions will not be denied. Surrounded by primitive forest and composed of most durable material, its antiquity is evidently very considerable. If undisturbed, it will preserve its integrity for an indefinite period.

By some curious persons an attempt was made, years ago, to pry into its secrets. A partial opening was effected in the breast, but with what results we could not learn. It excites no surprise that the eagle should have been selected in ancient times as a symbol of all that was swift, powerful, watchful, daring, and noble. Of its feathers was the battle-flag of the Creeks made. Their council-lodges were surmounted with

carved images or stuffed skins of this regal bird. None among the Cherokees, save approved warriors, were permitted to wear its plumes. To this king of the feathered tribe were religious honors paid by the Natchez, who regarded its feathers not simply as ornaments and trophies, but as marks of dignity and insignia of no common import.

About a mile and a half from Lawrence's Ferry, on the Oconee River, and situated on a stony ridge near the main road, on the plantation of Mr. Kinchen D. Little, in Putnam County, is another of these bird-shaped mounds. Like the former, it is composed wholly of bowlders of white quartz rock, collected from the hill on which it stands. (See Fig. 2.)

FIG. 2.



Scale 40 *feet to* 1 *inch.*

Bird-shaped stone mound in Putnam County, Georgia.

Its dimensions do not materially differ from those of the tumulus on the Scott place. The tail, however, is bifurcated. The head of the bird lies to the southeast, and its wings are extended in the direction of northeast and southwest. The entire length of the structure, from the crown of the head to the end of the tail, is 102 feet and 3 inches. For a distance of twelve feet the tail is bifurcated, and just above the point of bifurcation it is 12 feet wide. Across the body, and from tip to tip of the wings, the tape gave us a measurement of 132 feet. The body of this bird, which is evidently lying upon its back, is stouter than

that of the eagle, being 76 feet in diameter. Its wings are relatively shorter. The proportions of the head, neck, and tail are tolerably well observed. What particular bird this tumulus is designed to typify, we are at a loss to suggest. The altitude at the breast is about 5 feet, and from that point the structure tapers to the head and tail, which are some two feet high. At the tips of the wings, which are short and curved, the height is not more than a foot and a half. The ridge upon which this mound rests has never been cleared.

Surrounding this bird-shaped tumulus is an inclosure of rocks similar to those of which the mound is built. This stone-circle is symmetrical in outline, and at its nearest approach passes within a few feet of the tips of the wings.

Crowning the elevated ridges by which this county is traversed, are occasional rock-mounds of artificial origin. Usually from 4 to 8 feet high, and with base diameters of from 30 to 40 feet, they are circular in form, and are composed of the fragments of milky quartz so common in the region. Some have been opened, and from them have been taken human bones and relics of various sorts. Manifestly such are grave-mounds, it being easier in the rocky neighborhood to heap such stone-piles above than to cover the dead with earth. Of this class of tumuli we instance one on the plantation of Dr. J. T. de Jarnette, 12 miles from Eatonton and about a mile from the Oconee River, and another on the land owned by Capt. A. S. Reid, four miles from Eatonton and near Little River.

It was intimated by some of the early observers that tumuli of this description were not infrequently temporary in their character, and designed as a protection to the dead who perished away from their homes, until such time as they could be conveniently removed and carried back for interment in the established burial-grounds of the tribe or community of which the deceased were members. While it may be true that some, and perhaps many of the smaller rock-piles so frequent in many portions of Cherokee Georgia, may have originated in this way, we are of opinion that the substantial structures to which we have alluded are permanent in their character, and were erected as enduring memorials of the primitive dead of this region. Surely no more lasting monuments could have been devised at that early period.

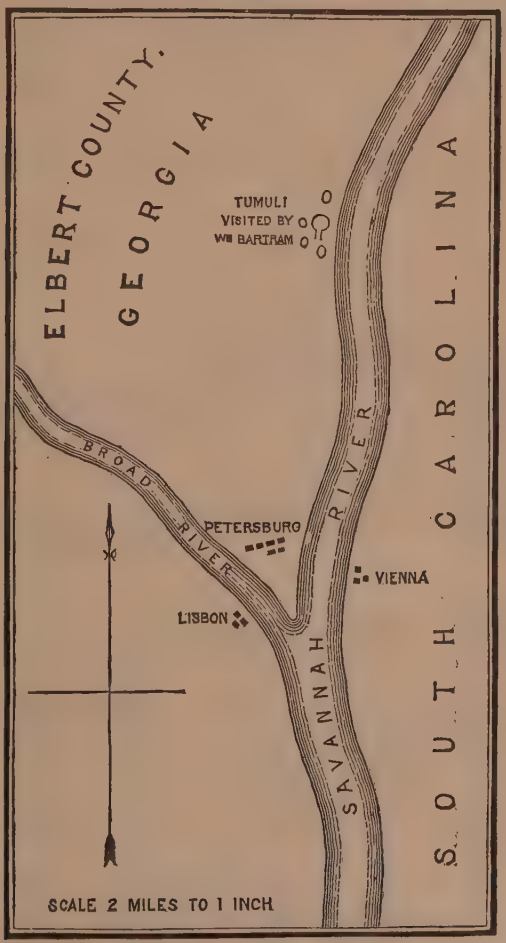
The existence of two distinctly marked bird-shaped mounds, of firm construction and excellent proportions, within the territory occupied by the Southern tribes, is deeply interesting, and will attract the attention of the student of American archæology.

II.

ANCIENT TUMULI ON THE SAVANNAH RIVER, VISITED BY WILLIAM BARTRAM, IN 1776.

Near the close of a spring day in 1776, Mr. William Bartram, who, at the request of Dr. Fothergill, of London, had been for some time studying the flora of Carolina, Georgia, and Florida, forded Broad River just above its confluence with the Savannah, and became the guest of the commanding officer at Fort James. This fort was situated on an eminence in the forks of the Savannah and Broad, equidistant from those rivers, and from the extreme point of land formed by their union. Fort Charlotta was located about a mile below, on the left bank of the Savannah. The stockade of Fort James was an acre in extent.

Fig. 1.

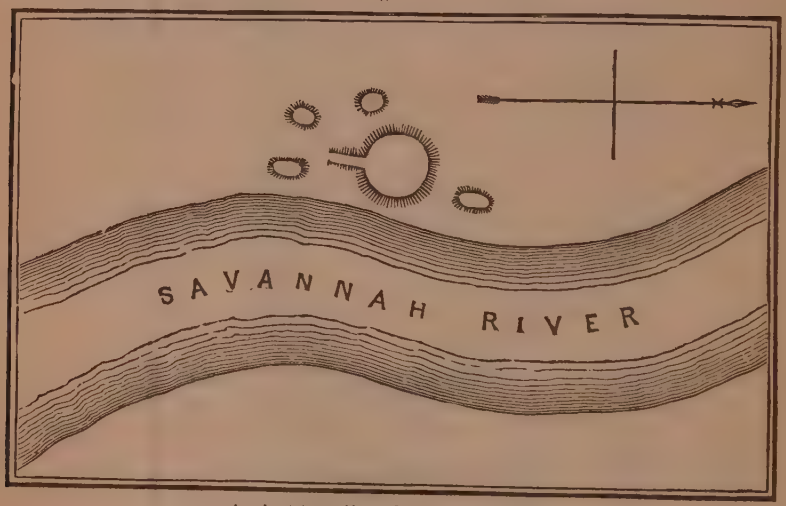


Ancient tumuli on the Savannah River.

Attended by the polite surgeon of the garrison, Bartram made an excursion up the Savannah River, "to inspect some remarkable Indian

monuments," four or five miles above the fort. Of them he writes as follows: "These wonderful labors of the ancients stand in a level plain very near the bank of the river, now 20 or 30 yards from it. They consist of conical mounts of earth, and four square terraces, &c. The great mount is in the form of a cone, about 40 or 50 feet high, and the circumference of its base two or three hundred yards, entirely composed of the loamy, rich earth of the low grounds; the top or apex is flat; a spiral path or track leading from the ground up to the top is still visible, where now grows a large, beautiful spreading red cedar (*Juniperus Americana*). There appear four niches excavated out of the sides of the hill, at different heights from the base, fronting the four cardinal points; these niches or sentry-boxes are entered from the winding path, and seem to have been meant for resting places or lookouts. The circumjacent grounds are cleared and planted with Indian corn at present, and I think the proprietor of these lands, who accompanied us to this place, said that the mount itself yielded above one hundred bushels in one season. The land hereabouts is indeed exceeding fertile and productive."

Fig. 2.



Ancient tumuli on the Savannah River.

Unable satisfactorily to determine the precise object the aborigines had in contemplation in the erection of this striking monument, he hazards the conjecture that the Indians formerly possessed a town on the river bank, and raised this mound as "a retreat and refuge in case of inundations, which are unforeseen, and surprise them very suddenly, spring and autumn."

What were the uses of the smaller elevations he does not suggest.

Wishing to note the changes which might have occurred during the past hundred years, we visited these tumuli a few weeks since. The attendant mounds, which are mainly grave-mounds, had been materially wasted by the plowshare and the influences of the varying seasons.

The tetragon terraces had lost their distinctive outlines, and were little more than gentle elevations; their surfaces littered with sherds of pottery and flint chips, and occasionally with fragments of human bones. Freshets had sadly marred the level of the adjacent space. Overleaping the river bank, the turbid waters had carved deep pathways in the surface of the valley on both sides of the "great mount." There it remained, however, wholly unaffected by these unusual currents. It had evidently suffered no perceptible diminution in its recorded dimensions. The Savannah River still pursued its long-established channel, but "the four niches or sentry-boxes," if they formerly existed, were entirely gone, and of "the spiral path or track leading from the ground up to the top" we could discover no trace. On the south a roadway, about 15 feet wide and commencing at a point some distance from the base of the mound, leads with a regular grade to the top. This manifestly furnished the customary means of ascent, as the sides are too precipitous for convenient climbing. This feature seems to have escaped Mr. Bartram's observation.

Not having been cultivated for many years, the apex and sides of this truncated cone are now clothed in a luxuriant growth of trees and swamp cane. Attired in such attractive garb, this tumulus forms a marked object in the profile of the valley from which it springs. Proofs of long-continued occupancy, by the aborigines, of the adjacent territory are abundant. Ancient burial-places, the sites of old villages, traces of open-air work-shops for the manufacture of implements of jasper, quartz, chert, greenstone, and soapstone, refuse piles, and abandoned fishing resorts, are by no means infrequent along both banks of the Savannah River for many miles. Upon the advent of the European the circumjacent valley was found cleared and in cultivation by the red men, who here had fixed abodes and were associated in considerable numbers. The Southern tribes, in the sixteenth century, subsisted largely upon maize, beans, pumpkins, and melons. These they planted, tended, and harvested regularly. Of their agricultural labors at the dawn of the historic period we have full accounts.

So vast are the proportions of this largest mound that we are persuaded it rises beyond the dignity of an artificial place of retreat, elevation for chieftain-lodge, or mound of observation.

It appears entirely probable that it was a temple-mound, built for sun-worship, and that it forms one of a well-ascertained series of similar structures still extant within the limits of the Southern States. These Florida tribes, as they were called in the days of De Soto, worshiped the sun and were frequently engaged in the labor of mound-building. Over them ruled kings who exercised powers well-nigh despotic. Often were the concentrated labors of the nation directed to the accomplishment of allotted tasks. Hence, within the territory occupied by these people, we find many traces of early constructive skill of unusual magnitude.

The material employed in erecting this large tumulus differs from the soil of the surrounding bottom. It is a dark-colored, tenacious clay,

while the surface of the valley is covered with a micaceous loam readily dissolving into an almost impalpable powder. Near by are no traces of pits or excavations. Nor are there indications that any earth was scraped up around the base. These facts afforded confirmation of the statement made by the present owner of the plantation upon which these tumuli are located, that the big mound had been built with clay brought from the Carolina side of the Savannah River. There clay abounds; and we were informed that in the side of the hill immediately opposite, the excavations may still be seen whence the tough material was obtained for heaping up this mound. This tumulus is one of the finest within the limits of Georgia, and should be classed with the truncated pyramids on Tumlin's plantation in the Etowah Valley, with the largest of the East Macon mounds, and with that frustrum of a four-sided pyramid on Messier's place, in Early County.

III.

ANCIENT TUMULI ON THE OCONEE RIVER.

About a mile and a half north of the Fontenoy Mills, in Greene County, Georgia, and located on the left bank of the Oconee River, are three tumuli surrounded by traces of extensive and long-continued inhumations. The largest (A) is situated rather more than 100 yards



Ancient tumuli on the Oconee River.

east of the river, and rises about 40 feet above the level of the valley. In general outline it may be described as a truncated cone. Its apex diameters, measured north and south, and east and west, were respectively, 65 and 68 feet. At the base, however, the flanks are extended in the direction of the east and west to such a degree that there is a difference of 35 feet between the base-diameters running north and south, and east and west; the former being 133 feet and the latter 168 feet. At the center of the top may be seen a circular depression, some 20 feet wide and 2 feet deep. Toward the north the face of this tumulus is quite precipitous. When first observed by the European, this monument was covered with a growth of trees as dense and apparently as old as that of the circumjacent lowlands. When the neighboring fields were cleared, this mound was also denuded of its vegetation and cultivated, its rich surface yielding generous harvests both of corn and cotton. Although now overgrown with brambles and small trees, which materially retarded minute inspection, it appeared quite probable from the scars on the surface of the valley in the immediate vicinity, that some severe freshet years ago impinged upon the northern base of this mound and carried away a considerable portion of its northern flank.

Rather more than 100 yards to the north of this tumulus, and trending to the northwest, is an irregularly shaped excavation (B), at present from 10 to 15 feet deep and partially filled with water, from which the earth used in the construction of these tumuli was obtained.

As yet no attempt has been made to open the large mound, but against its eastern face the overflowing waters of the Oconee at one time dashed, wearing it away for some distance and leaving there a perpendicular front of 10 feet or more. Here were disclosed human bones, the skeletons of dogs, and large beads made of the columns of the *Strombus gigas*. If this partial revelation be accepted as indicative of the general contents of the tumulus, it should be classed as a huge grave-mound. We decline, however, adopting this conclusion without further information. It may be that the remains and relics then unearthed belonged to later and secondary interments. Instances of this sort, as we well know, are of frequent occurrence.

Two hundred yards to the south is an elliptical grave-mound (C), not more than 4 feet high, but covering a considerable area. This structure, in the direction of its major axis, is about 150 feet long. Its minor axis is two-thirds less. The surface and neighborhood abound with human bones, sherds of pottery, fragments of pipes, shell-beads, muscle-shells, and various other relics. Across a shallow lagoon, and 250 yards southeast of the large tumulus, is a third mound (D), well preserved, 10 feet high, and quite level at the top. In every direction, except where it looks toward the north, its sides slope gently. Having been constantly cultivated for many years, this structure has encountered no inconsiderable waste. At the base its north and south diameter was 100 feet. Measured at right angles, the other diameter was 88 feet. Similar meas-

urements across the top indicated 50 feet and 40 feet. To the east, west, and south, are traces of spurs or graded ways for easy ascent.

This mound occupies a central and commanding position in the middle of a fertile alluvial field of fifty acres. Although its contents are unknown, we conceived the impression that it was designed as an elevation for a chieftain's lodge, since the Spanish historians mention the existence of artificial tumuli erected for this purpose. Around the base, and for a considerable distance on every hand, are traces of primitive occupancy, all persuading us of the fact that, in former times, this tumulus was surrounded by the dwellings of people who had here fixed their home.

The space adjacent to the large tumulus (A), to the extent of some four acres, appears to have been largely, if not exclusively, dedicated to the purposes of sepulture. Every freshet which sweeps over this area uncovers human skeletons, disposed in every direction only a few feet below the surface. So thoroughly and frequently has this territory been torn by freshets that it has lost its original level, and now exhibits on every hand heaps of broken pottery, quantities of human bones, and fragments of various articles of use, sport, and ornament. The freshet of 1840 was the first, so far as we can learn, which in a marked manner invaded the precincts of this ancient burial ground. Upon the subsidence of the waters many were attracted to the spot by the multitude of terra-cotta vessels, human bones, shell-beads, pipes, discoidal stones, grooved axes, celts, and other objects of primitive manufacture. One gentleman collected nearly a quart of pearls which had been perforated and worn as beads. The plantation negroes supplied themselves with clay pipes then unearthed. In the possession of not a few of them were seen strong clay vessels, thence obtained, which they used for boiling soap. Large calumets and other objects of special interest were secured by the curious and carried to their homes, where, for a season, they formed matter for speculation and idle talk, and in the end were either lost or broken. Subsequent inundations have brought to light similar proofs of sepulture and early manufacture, but this treasure-house has been so often visited and so carefully searched that its present yield falls far short of that which was encountered when the Harrison freshet invaded this place of the dead.

It is a sad fact that the denudation of the banks of these southern streams and the destruction of extensive forests in reducing wild lands to a state of cultivation have proved the proximate causes of serious injury to, and often of the total demolition of, many prominent and interesting aboriginal structures.

On the right bank of the Oconee River, about a mile and a half above its confluence with the Appalachee River, situated in the low grounds of the plantation of Mr. Thomas P. Saffold, is a circular earth mound some 20 feet high, covering about the eighth of an acre. The sides are sloping, as in the case of other conical mounds along the line of this

river, but the peculiarity which distinguishes it from its companions is that around the apex stout earth walls were raised to the height of several feet, thus causing a depressed or guarded top.

Near the banks of the Appalachee River, in Morgan County, may still be seen occasional artificial pits, some 4 feet in depth and 6 feet or more in diameter. Upon removing the *débris* of leaves and earth with which they are filled, their bottoms and sides indicate the influence of long-continued and intense fires. Fragments of pottery also occur in them. It would seem that they constituted a sort of rude oven in which the Indians baked their clay vessels.

We might multiply instances of tumuli still extant in the valleys of the Oconee and its tributaries, but having already described and figured those in East Macon and its vicinity,* enough has probably been said to convey an intelligent idea of the aboriginal monuments of this section.

ANTIQUITIES OF SPALDING COUNTY, GEORGIA.

By W. B. F. Bailey, *of Griffin, Ga.*

About three miles west of Griffin, in a field known to the inhabitants of this vicinity by the name of Walnut Level, is, from present appearances, a place where once a thrifty Indian village was situated; but whether inhabited by the Creek Indians or by the more ancient mound-builders is unknown. This field contains, in one place, a perfectly level plain of four or five acres, which, when first cleared, was a walnut grove, in which the Indian village was situated. East of the village, and not more than 100 yards distant, runs a beautiful little stream, now known as "Wilson's Mill Creek." This stream and the fertility of the land no doubt attracted the people of this ancient village. With the exception of broken pottery and a few arrow-heads, no relics are left to mark this spot; though I am told by the old inhabitants that when the field was first cleared they would plow up urns of a curious shape, but not deeming them of any importance left them on the ground; and nothing now remains but a vast quantity of broken fragments. Of this pottery there are thousands of pieces, ranging in size from that of a silver dime to pieces as large as one's hand. I have no doubt but that a man could gather five or six bushels of fragments in one day. This pottery is of two different styles of workmanship, one being plain and the other carved in the "cord fashion." These relics are fast disappearing, and in a few more years scarcely anything will remain except a few arrow-heads. One mile east of this is a small lake, about a quarter of a mile in length and 30 feet wide, with an average depth of 4 feet. On the banks of this lake and in the surrounding fields a great number of arrow-heads are scattered around. The water in the

*Antiquities of the Southern Indians, &c., p. 158 *et seq.*, New York, 1873.

lake is fast failing, having sunk about 4 feet in the last ten years, and ere long it, too, will be numbered with things of the past.

Judging from the alluvial deposits on its banks, this was, at the time when this Indian village flourished, a great lake for this part of Georgia. Fish of all species common to the country are found in great abundance here. From the number of relics found and the great quantity of fish at present in the lake, I have no doubt that this place was once their favorite hunting ground. About midway between the lake and village was an earth-work. I only hear this from others, as it was plowed down level with the ground long before I was born. People who have seen it say that it resembled the breastworks of the present day; that it was circular in form, inclosing about two acres, with a base 8 or 10 feet wide, 4 or 5 feet wide on the top, and an average height of 18 inches. They supposed, and some still think, that it was made by De Soto, and that he had a fight with the Indians here; others think that it was made during the Revolutionary war, while I attribute the work to a more ancient age, namely, t he "mound-builders." If this work was really done by the "mound-builders" (and there can be no doubt of it), it is the only trace left behind them in this vicinity. The idea that De Soto or any other man had a fight with the Indians at this place is, to say the least, absurd, for there are no implements of war found here other than the arrows used in hunting, whereas if a fight had taken place between De Soto and the Indians, some kind of war implements would have been found.

SHELL-HEAPS ON MOBILE RIVER.

By A. S. Gaines and K. M. Cunningham, *of Mobile, Ala.*

The Smithsonian Institution has received a very valuable collection of shell-heap relics from Simpson Island, at the mouth of Mobile River. They were sent by Mr. A. L. Gaines, land commissioner of the Mobile and Ohio Railroad, who gives the chief credit for their discovery and transmission to Mr. K. M. Cunningham, from whom the Institution has received several communications, accompanied by sketches of the specimens.

These shell-heaps are very numerous on the banks of the Mobile River at its mouth, especially upon Simpson Island, which forms the delta between the mouth of the Mobile and that of the Tensas. Many of them are the sites of market-gardens, and the shells from those most accessible to the water have been utilized in paving the stock-yards of the railroads, and the grounds around the cotton warehouses in Mobile. The one from which the relics in question were recovered is about 19 miles above Mobile, on the land of the Mobile and Ohio Railroad, and 200 feet from the water's edge. The heaps are composed almost entirely

of clam-shells, although a few specimens of *Arca incongrua*, *Neritina*, *Melania*, and *Fusus cinereus* are met with.

Human remains have been found in great abundance even upon the surface. Mr. Cunningham reports the discovery of portions of fourteen skeletons. Of the perfect crania found, one was very much distorted, the other was slightly flattened on one side. Bone implements were also recovered, sharpened at the end like a toothpick. But the most interesting part of the collection is the pottery, thousands of fragments having been recovered on this single occasion. Five entire vessels were saved, and fragments of one or two others which can be repaired. Of the entire vessels, No. 1, 18 inches wide and 14 inches deep, is composed of coarse material, shells and clay, brown outside and red inside. In shape it is an inverted conoid, with perpendicular rim. There is no ornamentation excepting a line drawn around the base of the neck. It contained human remains, and when found was covered by a flat dish in the same manner as the burial jars of Nicaragua. No. 2 is a flat inverted conoid, 7½ inches deep and 18 inches in diameter, angular at the widest part, and with perpendicular rim. The portion from the bulge to the neck is elaborately ornamented with sigmoid lines and dots, at intervals interrupted by figures which resemble a pair of hands or feet. This is a very unique specimen in smoothness and ornamentation. Several of the broken jars were similarly ornamented. No. 3 is similar in shape and ornamentation to No. 2, 3 inches deep and 6 inches wide. The rim was formerly furnished with knobs or handles. No. 4 is a plain, round-bottomed cup, 3¼ inches deep and 4 inches in diameter. No. 5 resembles in shape an ordinary dinner pot, 6 inches deep and 6 inches in diameter. It is to be hoped that further researches will be made in this interesting locality.

THE STOCK-IN-TRADE OF AN ABORIGINAL LAPIDARY.

(Mississippi.)

By Charles Rau.

In an essay entitled "Ancient Aboriginal Trade in North America," which was published in the Smithsonian Report for the year 1872, I attempted to trace the beginning of a division of labor among the former inhabitants of this country. I expressed the opinion that certain individuals, who were, by inclination or practice, particularly qualified for a distinct kind of manual labor, devoted themselves principally or entirely to that labor, basing my conjecture on the occurrence of manufactured articles of homogeneous character in mounds or in deposits below the surface of the soil. There is little doubt, for instance, that there were persons who devoted their time chiefly to the manufacture of stone arrow-heads and of other articles produced by chipping, among which may be mentioned those remarkable large digging tools

described by me several years ago,* and the oval or leaf-shaped implements made of the peculiar hornstone of "Flint Ridge," in Ohio. These latter, which bear much resemblance to certain palæolithic types of Europe, were first noticed by Mr. E. G. Squier, who found, many years ago, a large deposit of them in a low mound of "Clark's Work," in Ross County, Ohio. An excavation, six feet long and four feet wide, disclosed about six hundred specimens, which were standing edgewise, forming two layers, one immediately above the other. The deposit extended beyond the limits of the excavation on every side, and hence the actual number of specimens has not become known.† Since that time deposits composed of objects of corresponding shapes and of the same material have been discovered, generally under the ground, in Illinois, Wisconsin, and Kentucky; but the area of their distribution may be much greater. Dr. J. F. Snyder has described the Illinois deposits in the Smithsonian Report for 1876.‡ That of Beardstown, in Cass County, is of special interest. It contained about fifteen hundred leaf-shaped or round implements, arranged in five horizontal layers, which were separated by thin strata of clay. According to Dr. Snyder, another deposit, said to have consisted of three thousand five hundred specimens, was discovered in Fredericksville, Schuyler County, in the same State. Smaller subterranean deposits of flint arrow-heads, cutters, &c., have been met with in various States in the eastern half of this continent, the articles showing in many cases no traces of use whatever, and generally exhibiting a symmetrical order in their arrangement. Such facts naturally lead to the supposition that flint-chipping formed a special profession, and, furthermore, that the objects found in these hiding-places, or "caches", constituted the magazines of the aboriginal craftsmen. The deposit of Clark's Work, it should be stated, has been thought to owe its occurrence in a mound of peculiar structure to superstitious or religious motives, and thus to partake of a sacrificial character. This view, however, whether correct or not, has no bearing on the point in question, namely, the production of the chipped articles by way of trade.

The carved stone pipes, representing imitations of the human head, of quadrupeds, birds, &c., which were found in great number by Messrs. Squier and Davis in a mound of the group called "Mound City," not far from Chillicothe, Ohio, illustrate the highest development of early aboriginal art in this country.§ Their production required much skill and patient endurance, and hence we may infer that the manufacture of stone pipes formed in past times a branch of industry which was chiefly carried on by persons who possessed an extraordinary talent for this

* A Deposit of Agricultural Flint Implements in Southern Illinois, Smithsonian Report for 1868, p. 401.

† Squier and Davis: Ancient Monuments of the Mississippi Valley, Washington, 1848, p. 158; representations of the objects on p. 214.

‡ Deposits of Flint Implements, p. 433.

§ Ancient Monuments, &c., p. 242, &c.

peculiar kind of work. There are to this day pipe-makers among the Ojibway Indians, and probably among other tribes.

In corroboration of the foregoing, I may state that certain handicrafts were practised to some extent by the North American Indians at the time of their first intercourse with the whites. "They have some," says Roger Williams, "who follow onely making of Bowes, some Arrowes, some Dishes (and the women make all their Earthen Vessells), some follow fishing, some hunting: most on the Sea side make Money, and Store up shells in Summer against Winter whereof to make their money."* These remarks, of course, relate to the New England tribes, with whom Roger Williams used to associate; but a later writer, Lawson, gives a similar account of the Southern Indians, among whom labor was doubtless still more systematized, considering that they had attained a somewhat higher degree of civilization than their Northern kinsmen. It is known that until within late years the manufacture of arrow-heads was practised as a profession by certain individuals among several Indian tribes.

I will now proceed to describe a deposit of aboriginal manufactures, which illustrates the subject of division of labor among the earlier inhabitants of this country better than any other discovery of kindred character with which I have become acquainted.

In the spring of 1876, Mr. T. J. R. Keenan, of Brookhaven, Lincoln County, Mississippi, presented to the National Museum a collection of jasper ornaments, mostly unfinished, which had been found in Lawrence County, in the same State, forming a deposit of a very remarkable character. Being desirous of learning the particulars of this discovery, I addressed a letter to Mr. Keenan, and obtained from him the desired information. The deposit was accidentally discovered on the farm of Anthony Hutchins, situated on the east side of Silver Creek, about one mile distant from Hebron church, in the northeastern part of the above-named county. While Mr. Huchins's son was engaged one day in July, 1875, in ploughing a cotton-field, entirely free from pebbles and stones of any kind, a grating of the ploughshare attracted his attention, and upon examination he found that he had struck the deposit, which appeared originally to have been buried two feet and a half below the surface, filling an excavation of about eighteen inches in diameter. The arrangement of the articles constituting this deposit will be described hereafter. They all consist of jasper of a red or reddish color, which is sometimes variegated with spots or streaks of a pale yellow. But few of these objects, which were undoubtedly designed for ornament, may be considered as entirely finished.

The following is an inventory of the specimens sent to the National Museum by Mr. Keenan:

1. Twenty-two pebbles of jasper, showing no work whatever. They are irregular in shape and mostly small, being from half an inch to an inch and one-fourth in size.

* A Key into the Language of America (London, 1643); Providence, 1827; p. 133.

2. Twelve rudimentary ornaments of different forms, brought into shape by chipping.

3. Three polished pieces with narrow grooves, showing that cutting was also resorted to in the manufacture of the objects.

4. Two hundred and ninety-five beads of more or less elongated cylindrical shape, measuring from one-fourth of an inch to three inches in length, and from one-fourth of an inch to one inch in thickness. Though they are polished, they exhibit but rarely a perfectly regular cylinder form. Ten of them show the beginnings of holes, in most cases at one end.

5. One hundred and one round beads of a more compressed or discoidal shape. They are from one-eighth to five-eighths of an inch long, while their diameters vary from one-fourth to three-fourths of an inch. They are polished, and only five of the number exhibit incipient holes.

6. Nine polished ornaments of elongated flattish shape, showing an expansion on each side (like Fig. 10). They measure from an inch and one-fourth to two inches and one-fourth in length, and from three-fourths of an inch to an inch and one-fourth in width across the middle. One specimen is partly drilled.

7. Two specimens of similar character, but expanding on one side only (Fig. 11). They are from an inch and a half to two inches in length and seven-eighths of an inch wide across the middle.

8. One large ornament showing two expansions on each side (Fig. 12). A more minute description will follow.

9. Two small animal-shaped objects. They are about an inch long and well polished.

10. Two semicircular polished pieces, probably designed to be worked into the shapes of animals.

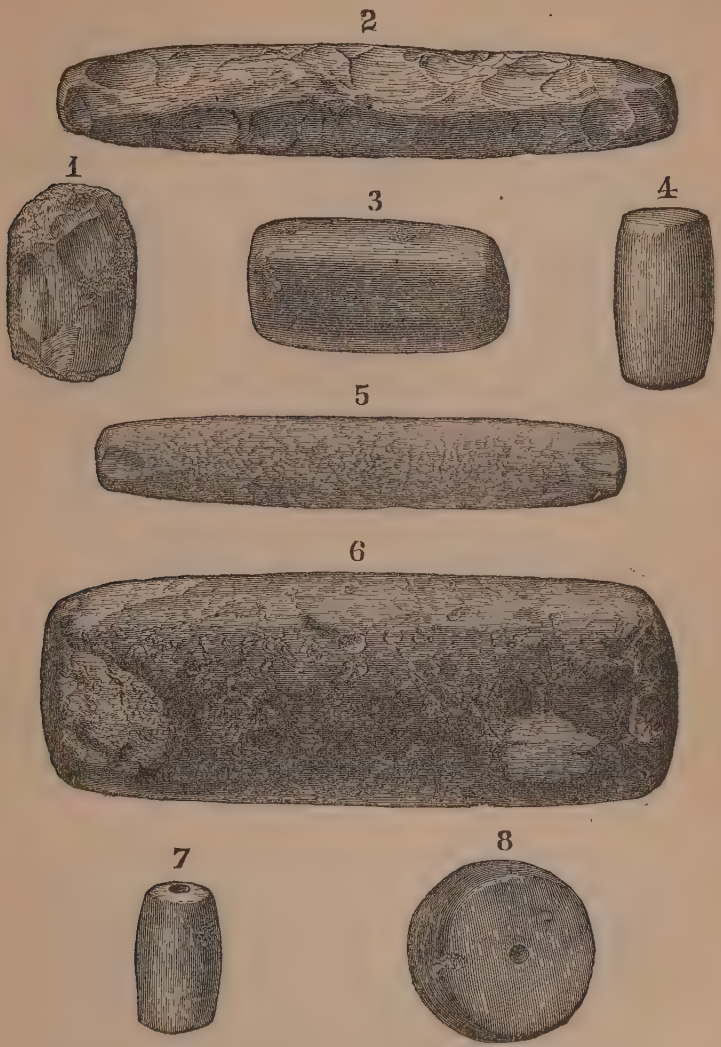
There are four hundred and forty-nine pieces in all. Mr. Keenan has kept for himself sixteen specimens, and four had been disposed of before he became the owner of the collection. One of the latter was drilled entirely through. Hence the entire deposit consisted of four hundred and sixty-nine objects.

From the character of the inventory just given several inferences may be drawn.

There can hardly be any doubt that the deposit constituted the stock-in-trade of some aboriginal manufacturer of ornaments of jasper, which he made from pebbles of that material.* He shaped them by the operation of chipping before he proceeded to grinding, and he likewise applied the method of cutting in the manufacture of the articles. The cutting, however, was done after the piece had been reduced to a certain shape by grinding. The drilling of the beads and bead-like ornaments was the final process in their fabrication. This fact affords an additional

*According to Mr. Keenan's express statement, no jasper pebbles occur in the neighborhood of the place where the ornaments were entombed. They must have been brought from a distance.

proof that in this country stone objects requiring perforations were brought into perfect shape before the drilling was commenced. The same rule prevailed in Europe, as every one knows who has studied the stone antiquities of that part of the world.



Jasper ornaments from Mississippi (½).

The accompanying illustrations represent, in full size, typical specimens of the different classes of wrought articles composing the deposit.

Fig. 1.—A jasper pebble, chipped into the form of a cylindrical bead. The smooth surface of the pebble has not entirely disappeared.

Fig. 2.—A long, comparatively slender piece, designed for a bead. It shows the chipping very distinctly, though the sharp edges have been removed by grinding.

Fig. 3.—Polished cylindrical* bead (undrilled).

Fig. 4.—Very regular and well polished cylindrical bead of a fine red color (undrilled).

Fig. 5.—Long and slender bead, apparently not entirely ground into shape (undrilled).

Fig. 6.—Large cylindrical bead, which exhibits a rather rough surface, the traces of chipping not having been entirely removed by the grinding process (undrilled).

Fig. 7.—Small cylindrical bead, polished, but not regular in shape, and showing at one end the beginning of a hole, which forms a cylindrical cavity nearly three millimeters in diameter and two millimeters in depth.

Fig. 8.—Polished bead of discoidal shape, with incipient holes at both ends. One of the holes is merely indicated by a small depression; the other forms a cup-like cavity of two and a half millimeters diameter and two millimeters depth.

Fig. 9.—Ornament of elongated flattish shape, with an expansion on each side. It is unfinished, having been brought into shape by chipping alone.

Fig. 10.—Object of the same form; well polished, but not absolutely regular in outline. There can be no doubt that the ornaments of this description were intended to be drilled in the direction of the longitudinal axis. A broken specimen of the collection shows the commencements of holes at both extremities.

Fig. 11.—Polished ornament of similar character, exhibiting an expansion or projection only on one side (undrilled).

Fig. 12.—Large polished ornament of elongated flattish form, with two expansions on each side. The object is irregular in outline, the expansions being larger at one extremity than at the other. It is three-fourths of an inch thick in the middle. A longitudinal perforation was doubtless intended.

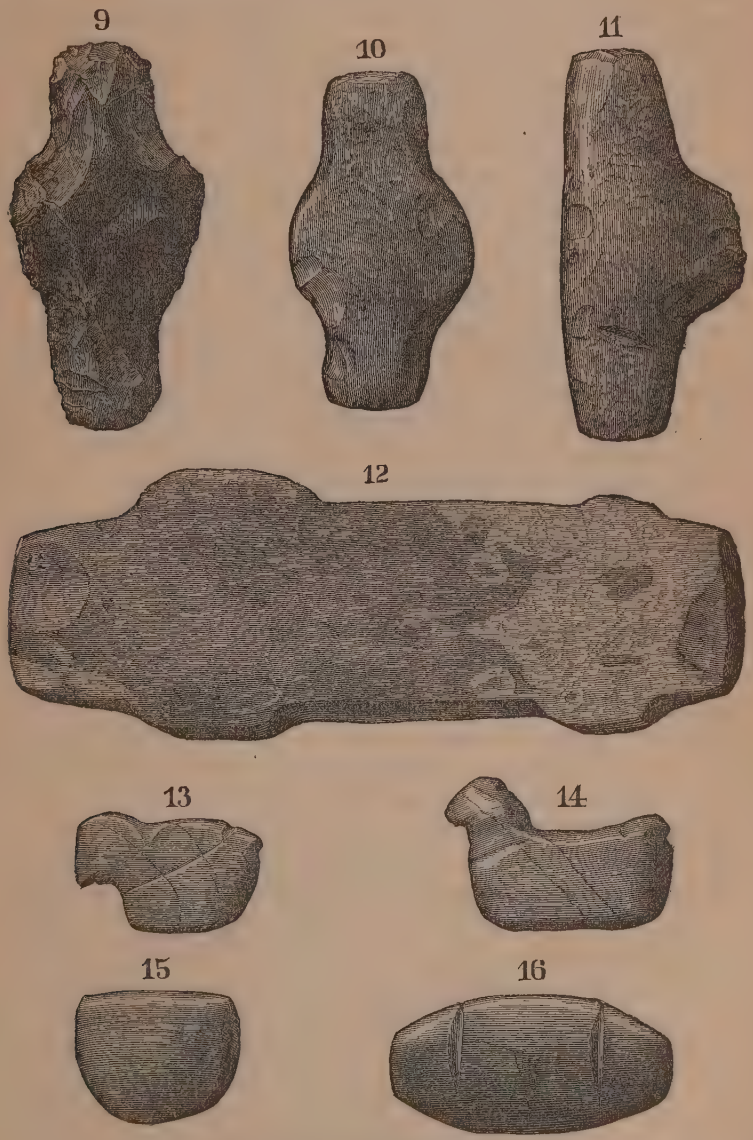
Fig. 13.—A small, flattish, bird-shaped object, made of beautiful cherry-red jasper, and well polished. The wings are indicated on both sides by slight grooves.

Fig. 14.—A similar polished object of dark-red jasper, in which the bird form is less distinctly expressed. Indeed, the maker may have purposed to represent some quadruped. It would be unprofitable to speculate on the use of these two carvings. They probably were merely toys, though it is not impossible that they had a totemic significance, or were designed to serve as charms. They could not well be worn about the person, and I doubt whether it was intended to perforate them.

Fig. 15.—A polished semicircular piece, perhaps designed to be worked into the shape of a bird; its size is exactly the same as that of the original of Fig. 13.

* In this description of ornaments the term "cylindrical" must not be taken in a mathematical sense, as I merely intend to indicate by it an approximate resemblance to a cylinder.

Fig. 16.—A polished piece, of a compressed oval shape, showing two parallel incisions in the direction of the minor axis. They were evidently made with a sharp flint tool. It is probable that this specimen illustrates a stage in the manufacture of a small animal-shaped trinket, like those already described, the piece being almost too flat to be made into a bead of cylindrical form.



Jasper ornaments from Mississippi (½).

It now remains to be stated in what manner the objects forming the deposit were arranged. The large piece, represented by Fig. 12, lay flat on the bottom of the hole; the long and massive cylindrical beads were

placed on end, on and around it, as closely as possible, and the smaller objects were spread over them in a rather promiscuous way.

The owner of the articles here described, we may suppose, had no intention of leaving them buried in the ground; he would some day have recovered them, had circumstances permitted. Death, captivity, or removal to another part of the country, from which he never returned, may have frustrated his design. The deposit in question shared the fate of many others which have been preserved to our time, in order to add, as it were, to our knowledge of the former occupants of this country.

It would be a vain endeavor to offer any conjecture as to the age of the deposit. The objects appear absolutely fresh, not showing the slightest alteration of the surface. Jasper, however, is a very hard substance, capable of resisting the influences of exposure for ages. On the other hand, there is nothing that would militate against a comparatively recent, though pre-Columbian, origin of the deposit.

It must have been a very difficult task to work a stone as hard as jasper without the proper appliances, and we cannot but admire the skill, and, above all, the patience of the artist or artists who fashioned the ornaments from such an obdurate material. Yet it is known that even at the present time mineral substances of equal hardness are shaped and perforated in the most primitive manner by tribes occupying a very low position in other respects. The execution of such work is but a trial of endurance, a quality displayed in an eminent degree by uncivilized man when his mind is bent upon a definite purpose.

OBSERVATIONS ON A GOLD ORNAMENT FROM A MOUND IN FLORIDA.

By Charles Rau.

In December, 1877, Mr. Damon Greenleaf, of Jacksonville, Florida, sent for examination to the National Museum a curious relic of gold, lately discovered in a mound in Manatee County, Southern Florida, with a request for information as to its probable origin and use.

The accompanying illustration represents the object in question reduced to one-half of its natural size, the original measuring exactly nine inches from the point to the middle of the opposite curve. It is cut from a flat piece of gold plate, not quite a millimeter in thickness, and somewhat thinner toward the edge. The specimen is broken in two pieces, as indicated by the dotted line in the figure; but the two parts fit well together, and thus the original character of the object remains unaltered. On the whole, it is in a good state of preservation, though the effects of long exposure are plainly visible. Both faces appear bright and smooth, and the engraved lines, which represent exactly the same pattern on both sides, seem to be as fresh as on the day when they were traced.

Little need be said concerning the shape of the ornament, considering that all its features are distinctly expressed in the cut. The maker

evidently intended to represent a bird's head, the neck of which forms a blade-like prolongation, and the grotesque execution clearly illustrates



Gold ornament from a mound in Florida, and head of the ivory-billed woodpecker. (½).

the curious taste characterizing the ornamental work of the North American Indian. It never would occur to a person of Caucasian origin to represent a bird's head in the peculiar manner here exhibited. The eye of the bird, it should be stated, has been formed with great regularity by the process of punching from the under side, and perfectly resembles in size and convexity the head of a common brass tack. However clumsy the design of the object may appear to a common observer, the ornithologists of the National Museum have discovered the prototype that was before the aboriginal artist's mind. The truncated bill and recurved crest leave no doubt that he intended to represent the ivory-billed woodpecker (*Picus principalis*, Linn.; *Campephilus principalis*, Gray), a bird quite frequent in Southern Florida, but not found at any great distance from the Gulf of Mexico. To facilitate comparison, a half-size sketch of the head of the ivory-billed woodpecker is placed in juxtaposition with the cut representing the aboriginal relic.

The composition of the gold plate from which the specimen is made indicates its post-Columbian origin. Having been forwarded, through the courtesy of Mr. E. B. Elliott, chief clerk of the Bureau of Statistics, to the Mint at Philadelphia, for the purpose of ascertaining its weight and composition or fineness, it was found to weigh 1.53 ounces (troy), and to consist exclusively of gold and silver, in the proportion of 893 parts of gold to 107 parts of silver. Consequently, the amount of gold therein contained is 1.366 ounces, and of silver 0.164 ounce (troy). The metal value of the relic is twenty-eight dollars and forty-five cents. According to Mr. Elliott's statement, its composition corresponds almost exactly with that of the "ounce" of gold or quadruple of Spain bearing the date of 1772; and this circumstance is not without significance, in so far as it seems to point to the source from which the material of the figure was derived. It may have been given by Spaniards to some

Indian, who fashioned it, according to his taste, to serve as a totemic emblem or ornament, perhaps designed to form a part of the head-dress; for, though a small elongated aperture is formed by the inner curve of the bird's neck, I hardly deem it likely that the object was intended for suspension. The Florida Indians, it is well known, paid particular attention to the decoration of their heads, and hence it is not an improbable conjecture that it once embellished the crown of some chief or brave while living, and was afterward placed in his grave, in accordance with aboriginal custom.

Whether the figure was brought into shape by hammering a large gold coin or a bar of gold, or was made from a piece of sheet gold, cannot now be decided. The surfaces certainly look as though they had undergone the process of beating; but it is just as likely that the ornament was made from a piece of gold plate furnished by whites. That the Indians were skillful in working metal in a cold state is shown by the implements and ornaments of copper found in various parts of the United States, more especially in the neighborhood of Lake Superior, where their supplies of native copper were chiefly obtained. Even modern Indians practise the art of working silver dollars, beating and cutting them into tasteful gorgets, ear-rings, and other objects of personal adornment. On the other hand, there is no ground whatever for supposing that the Indians north of Mexico possessed the skill of casting gold, and far less of producing an alloy like that of which the Florida ornament is composed.

While I am of opinion that the material of the relic was obtained from whites, I ascribe (as stated) the work itself—that is, the cutting out of the figure and the tracing of the lines—to the agency of an aboriginal artist. The ornamental lines, though incised with a steady hand, are not uniform in width, and in some places the tracing forms a double line, as though the implement used in lieu of a graver had not been provided with a sharp point. A knife which has lost its extreme point would produce such lines; perhaps also a pointed flint. The latter alternative, however, is hardly admissible, considering that at the time when the object was made, implements of such primitive character probably had been superseded by more efficient instruments of iron or steel. The North American Indians, like other savages, were not slow in recognizing the superiority of the white man's tools, and adopted them without hesitation.

Though it would be hazardous to pronounce a definite opinion concerning the age of the relic, it may be assumed that it is not very old. Its origin may not date back more than a century. It was perhaps made during the second period of Spanish supremacy in Florida, which lasted from 1780 to 1821, when the province was ceded to the United States. The ornament was taken *from the centre* of the mound, and doubtless formed a part of a primary burial. This fact affords an additional evidence that mound-building was continued in this country after

its occupation by Europeans. "The man who dug it out," says Mr. Greenleaf, "had no idea that it was gold. He had been digging all day, and was just giving up the work, when, with a final desperate blow, he struck, broke, and brought to light the gold ornament. He then explored the rest of the mound carefully, but found nothing but fragments of pottery and crumbling bones."

Purely aboriginal relics of gold appear to be extremely rare in this country. According to Colonel Charles C. Jones, Indian beads composed of that metal have been met with in Georgia. He says: "Gold beads—evidently not European in their manufacture—have been found in the Etowah Valley, in the vicinity of the large mounds on Colonel Tumlin's plantation."* This statement is corroborated by Mr. M. F. Stephenson in an article on ancient mounds in Georgia, which was published in the Smithsonian Report for 1870. I am not aware that Indian relics of gold have been found in Florida in modern times; but mention is made of a small gold bell obtained in 1527 by the party of the unfortunate Pamphilo de Narvaez, immediately after his landing in Florida. It was discovered in one of the large houses (*buhios*), which the natives had deserted upon the approach of the Spaniards.†

We learn from the old accounts relating to the discovery and colonization of the large tract of land formerly called Florida that the aboriginal inhabitants were cognizant of the occurrence of gold in their districts. The grains of gold which the early Spanish visitors saw in the possession of the Floridians excited their cupidity, and inspired them with the hope of finding a second Mexico or Peru in the more northern portion of the new continent. Upon asking the Indians where the precious metal had been obtained, they were referred to the "Apalatcy" Mountains, in the north, from which rivers carrying particles of gold, silver, and copper were flowing. The Indian method of collecting these metallic grains is represented on plate 41, vol. ii, of De Bry's *Peregrinationes* (Frankfort on the Main, 1591), where the natives are pictured as using long tubes for this purpose. Jacques Le Moyne de Morgues, the artist of Laudonnière's expedition, to which the volume relates, probably drew the sketch from imagination, or according to what he had heard from the Indians, who were never noted for their veracity. The short Latin description accompanying the sketch closes with the statement that the Spaniards knew how to apply these treasures to their own use. Indeed, traces of mining operations which are ascribed to the Spaniards have been found in the gold district of Georgia. It would be foreign to my purpose to enlarge on this subject; but I will refer to two articles by Dr. D. G. Brinton, which treat of this early

* Antiquities of the Southern Indians. New York, 1873, p. 48.

† "Un de ces buhios était si grand, qu'il pouvait contenir plus de trois cents personnes: les autres étaient moins vastes; nous y trouvâmes une clochette en or parmi des filets."—*Relation et Naufrages d'Alvar Nuñez Cabeça de Vaca.* Paris, 1837, p. 24. (Ternaux-Compans Collection.) The Spanish original was published in the year 1555 at Valladolid.

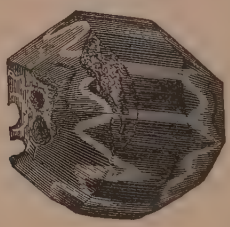
mining: one forms the third appendix to his excellent little work entitled *Notes on the Floridian Peninsula;* the other is published in the *Historical Magazine*, vol. x (1866), p. 137, under the title "Early Spanish Mining in Northern Georgia." Additional information on the subject is to be found in Colonel Jones's work, to which I have referred on the preceding page.

ON A POLYCHROME BEAD FROM FLORIDA.

By Prof. S. S. Haldeman.

This bead (Fig. 1), now in the United States National Museum, is of a kind known to archæology as the star pattern, because the white between the exterior blue and inner red forms a terminal star or zigzag band when the original cylinder is ground into an oval so as to expose the interior colors. Examples occur of various sizes from about two inches in length and one and a half in diameter to about one-fourth of an inch in size, the latter being spheric or oblate and as distinctly

Fig. 1.



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colored as the large ones. There is a specimen about an inch and a half long in the ancient Egyptian department of the Louvre (horizontal case Q), and, according to my recollection, a specimen from Dakkeh (Nubia) in the British Museum (horizontal case E, No. 6294 *d*) is larger. The Slade collection in the British Museum contains two of the same character.* A large one found in England with Samian cups and Roman buckles is figured in the Proceed. Brit. Archæol. Assoc. 1848, vol. 3, p. 328; Faussett† figures an example from Gilton, England; and another is described in the Archæologia (1851, vol. 35, pl. 5, fig. 10), the locality unknown, but Mr. B. Nightingale says examples occur along the Rhine and are to be seen in the museums of Mannheim and Baden. Mr. Morlot, of Lausanne, gives colored figures of two examples in the museum at Copenhagen.‡ That of fig. 1 was said to have been found near Stockholm, the other in an antique grave in

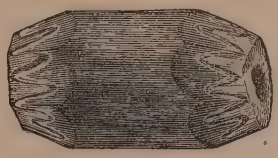
* Catalogue of the collection of glass formed by Felix Slade, esq., F. S. A., with notes on the history of glass-making, by Alexander Nesbitt, esq., 1871, p. 10, fig. 21.

† Inventorium Sepulchrale, 1866, pl. 5, fig. 2.

‡ Proceed. Am. Philosoph. Soc., Nov., 1862, p. 111–114 and 119–120.

Denmark. He also copies (fig. 3) one of Schoolcraft's figures of a smaller cylindric bead from the ossuaries at Beverly, Canada. Somewhat similar to the Stockholm specimen is a bead in the National Museum (Fig. 2) from Santa Barbara, Cal., in which the exterior blue is

Fig. 2.



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minutely and thickly speckled with yellowish points. The same collection has examples of the small spherical kind from graves at Lima, N. Y.; and I have a specimen found on the Susquehanna, with other remains, in digging the Pennsylvania canal, about the year 1830.*

The exterior blue is usually more or less clearly striped with a lighter tint, owing to the ridges of the interior white shining through. In all the specimens, and in such as I have seen in Europe, the order of the colors toward the interior is blue-white-red-white, with an additional central color in some of the larger ones, that of the large Louvre example being dark blue. This order is present in modern Venetian beads, of which I have examples much like that of Santa Barbara, Cal., and in those from New York and the Susquehanna, but the last two are more neatly made, the white, wavy band in the Susquehanna specimen being very slender, delicate, and regular. The external tint of the modern Venetian cylindric beads is blue, green, red, or longitudinally striped with several colors, and the Louvre has blue and also green ancient Egyptian specimens.

Mr. Morlot's paper is intended to show that the Northmen received these beads from the Phœnicians and carried them to America, a view which is opposed by Mr. A. W. Franks, F. S. A., of the British Museum, who thinks that the Beverly specimen figured by Schoolcraft is Venetian of the fifteenth or sixteenth century,† a view which is probably correct for all the North American examples. Of these, the New York specimens show signs of oxidation, while that from the Susquehanna is untarnished.

* Proceed. Am. Phil. Soc., May, 1869, vol. 11, p. 369. Mr. Thos. Masterson, of Columbia, Pa., has added to my cabinet a fine specimen, but little tarnished, from a grave in Tioga County, Pa., and he has the longitudinal half of another, 1⅜ inch long and 1 1/16 in diameter, found at Turky Hill, below Columbia, Pa.

† Proceedings of the Society of Antiquaries, January 28, 1864. Lubbock, Prehistoric Times, ch. 3. I am indebted to the kindness of Mr. Franks for valuable ancient and modern additions to my cabinet of beads.

And yet, the manufacture of the star pattern and other kinds of beads in glass and enamel, with varicolored spots and circles, is of great antiquity. The art seems never to have been lost, and in later times to have been chiefly cultivated at Venice, where more than five hundred varieties are made. A local historian, Mr. Samuel Evans, of Columbia, Pa., says the natives along the Susquehanna traded with the French for fire-arms before 1608, and he mentions a trading-post at the mouth of the river, established in 1631 by a person named Claibourne.* Charles C. Jones † mentions that De Soto found European beads in possession of the natives as early as 1540, and they seem to have been valuable articles of trade at various periods and among many nations. They are abundant in European mounds, where they occur in various shapes and variegations of color, as may be observed in works devoted to antiquities.‡ The magnificent Cesnola collection in New York has varicolored examples from Cyprus. The Kertch example (Archæologia, 34, pl. 5, f. 20) is blue with white circles. The same tints occur on Egyptian beads in the Louvre, and on Phœnico-Greek specimens in the Liverpool Museum. The British Museum has beads from Tyre of a dark ground, some with white circles, others with transverse zigzag bands.

A Venetian bead known as "cornaline d'Aleppo" is widely spread. It is red, with a white or yellowish center, and when strung or worked into ornaments the white is scarcely apparent, so that it might be supposed that red beads would answer as well. Possibly they are more pleasing to the eye when sold in bulk. I have specimens of it from Abyssinia, Algeria, in native work of Demerara, in a medicine-bag probably from the Rocky Mountains, in moccasins of the kind made by the Indians of New York and Canada, and Mr. W. H. Holmes of the Hayden expedition picked up a specimen near the trail in the vicinity of the ancient ruins of the Rio Mancos, in Southwest Colorado. Mr. Holmes also found a small elliptic white enamel bead among the *débris* of the ruins, but

* Lancaster, Pa., Express, March 8, 1876.

† Antiquities of the Southern Indians, 1873, pp. 235–237, 520.

‡ Archæologia, 1851, vol. 34, cuts p. 117, and pl. 5, including a Sabine example (f. 27), two from Kertch (f. 20, 21), and three from Egypt. All these are varicolored. The spheric and sulcate forms, figs. 8, 13, 15, known as "Druid's beads," occur in Egypt, and are represented in a large and varied collection of ancient Etruscan specimens which I owe to the liberality of the distinguished archæologist, Signor Alessandro Castellani. Among its representatives of the plate referred to are fig. 20 (Kertch), 23 (cylindric, Nubia), 25 (triangular, Egypt), 27 (spotted, Sabine), and 35, with colored rings.

R. C. Neville, Saxon Obsequies, 1852, pl. 18–22, containing several hundred figures, mostly varicolored.

John Yonge Akerman, Remains of Pagan Saxondom, 1855, cuts p. xxviii, and colored plates 12 and 21, with thirty or forty varieties.

Faussett (op. cit.), pl. 5, 6, 7, figures in single tint and varicolored of about two hundred examples.

Achille Deville, Histoire de l'Art de la Verrerie dans l'Antiquité, 1873, pl. 78–9, varigated; pl. 5, unicolored.

even this is a Venetian pattern. Among many varieties of glass beads, the Wheeler Survey has the cornaline d'Aleppo from excavations near Santa Barbara, Cal. (Dos Pueblos, Big Bonanza), also another Venetian variety with the center black instead of white. Both kinds are used by the modern Utes. It deserves mention that Professor Henry has recently procured for the Smithsonian Institution a fine collection of Venetian beads for comparison in this branch of archæology.

COLORED BEAD DUG FROM A MOUND AT THE EXTREME NORTH END OF BLACK HAMMOCK, THREE MILES WEST OF MOSQUITO INLET, EASTERN COAST OF FLORIDA.

By A. M. Harrison, *Assistant, Coast Survey.*

Imbedded in the roots near one of the skulls was found a small gold bead, and another larger one of such peculiar material and construction that a description of it will not be amiss. (See Fig. 1, in preceding article). It is cylindrical, 1¼ inches long, 1 inch in diameter through the center, and one-half inch across the hexagonal ends. When taken from the ground, parts of its surface had a peculiarly pearly or iridescent appearance, due to oxidation. Upon my return home I divided it lengthwise, and gave one-half in its original condition to the Superintendent of the Coast Survey; the other I had polished, and it is still in my possession. It is brilliantly colored around the middle by dark and light blue longitudinal bars, tapering toward the ends of the bead, which are deep red, each bar being defined by a dead white line. Running lengthwise through the center is a variegated cylinder of opaque and semi-transparent enamel, or glass, which has a single perforation. Obviously, a tube arranged in concentric layers of different colors was first made, then cut into sections at intervals, and each section ground to the present shape. It is beautifully tinted, and plainly the work of a skilled artisan.

SHELL-HEAPS AT THE MOUTH OF SAINT JOHN'S RIVER, FLORIDA.

By S. P. Mayberry, *Cape Elizabeth, Me.*

Fort George Island lies at the mouth of Saint John's River, Florida. It embraces 1,100 acres of high and dry "hammock" land, surrounded on three sides by 1,800 acres of marsh. On the remaining part is a sandy beach, which also extends along the mouth of the river four miles. The island is very nearly level and covered with a dense growth of many varieties of wood, among which are live and water oak, magnolia, hickory, cedar, and pine. Mount Cornelia is a hill of sand about one-half mile from the shore. It is estimated that there are forty acres covered with large piles of oyster-shells, while many acres are covered with

them distributed evenly over the surface. In that climate, when not protected, they disintegrate with some degree of rapidity.

The larger deposit that we examined covered 1½ acres; the height at the point must have been 30 feet. In shape it resembled a bowl turned bottom side up. The upper surface was covered with a vegetable mold from 10 to 18 inches, upon which were growing forest-trees. We measured a live-oak which had a diameter of 32 inches. Six feet from the bottom was a layer of black vegetable mold following a course nearly parallel with the surface of the ground. It showed no indication that there were any trees growing in the space occupied by these deposits previous to their being transported there. The shells were, without an exception, single, and inside of the pile, where they had not been exposed to the influence of the climate, no signs could be discovered of their having been treated with fire. Large quantities of these shells are being carted off to make roads on the island, so that we had a good chance to see the interior of the pile. We were informed by the cartmen that human skeletons were found occasionally. A gentleman informed me that he had seen a piece of pottery on which was marked "1707." Adjoining the above pile was a depression resembling the inside of a bowl, the outside being irregular, and in one place it looked as though the side might have been forced out and that it was caused by a large body of water which had been inclosed and burst from its confinement. In the center of this deposit the shells were not three feet deep, while the walls were fifteen.

On another part of the island the proprietor informed me that among forest-trees of 2 and 3 feet diameter, on the deposits could be traced distinctly the rows and other indications of sugar-cane culture. About a month previous to my visit, Dr. Hall leveled a sand mound in front of his residence, in which were human skeletons, stone implements, and pottery.

ANCIENT MOUND IN WESTERN PENNSYLVANIA.

By William M. Taylor, *of Mount Jackson, Pa.*

This mound is about 35 feet in diameter and 5 feet high. Joining the circumference on the southeast is a projection 35 feet long, of the same height as the main part. This gives the mound a gridiron shape, with a very broad handle.

The site of the mound is on the Mahoning River, west side, second bench, and about a quarter of a mile from the stream. It is one-third of a mile from the mound back to the range of hills more than a hundred feet high. It is worthy of notice that the projection extends in a course parallel with the river on one side and the hills on the other.

In leveling this mound a number of graves and skeletons were discovered. There were also a few implements, bone beads, mica, &c.,

found. Most of the skeletons quickly crumbled upon exposure to the air. From Mr. Gibson, the owner, I obtained a large and well shaped skull. The under jaw is still attached, and most of the teeth remain.

On a former visit I picked up a number of bones that were lying loosely around after the attempt at leveling. The skeletons were surrounded by large flat stones set on their edges. These stones were brought from the hills, as there are none like them in the bottom. The earth of which the mound was built was also brought from a distance. It is quite different in color and quality from that near by. Some charcoal is found mixed in it. Flint chippings and arrow-heads are still lying around. Formerly various stone implements were found in the neighborhood. Last spring a colored man was plowing on the farm of Mr. C. B. Easby, on the hill-side, in sight of the mound, and less than half a mile from it. In the turning over of the sod he discovered an ancient cache. The stock or collection consisted of axes, hatchets, tomahawks, hoes, wedges, and a chain on which were strung several of the tomahawks. There were over twenty iron implements in all. No two of even the same kind were of the same size or shape; but one of the hoes was almost identical in shape and size with the hoes made for the Southern cotton-fields. Is it probable that the same race and generation used both the iron and stone implements? The iron tools have a very thick coating of rust upon them, and are evidently among the first iron implements ever used by any people in the valley of the Mahoning.

Near the mound once stood the Indian village of Kushkushkee, or Kaskaskunk. Pakanke, the Delaware chief, and Glikkikan, a celebrated orator of the Delaware tribe, lived here. It is probable that Christian Frederick Post visited the Indians in this town, by appointment of the governor of Pennsylvania, in 1758. "Again, in 1761, Post repeated his visit; not on this occasion in the capacity of a political envoy, but as an ambassador of the gospel."—*Black Robes.*

This was the year before the establishing of the Moravian missionary station and the founding of Friedenstadt, nine miles below on the Beaver River, near the present town of Moravia.

DEPOSIT OF ARROW-HEADS NEAR FISHKILL, N. Y.

By Edwin M. Shepard, *of Norfolk, Conn.*

This interesting discovery of arrow-heads was made upon the farm of Mr. George Allerton, at Green Haven, Dutchess County, New York. The farm is situated in a beautiful valley about twelve miles from Fishkill on the Hudson. It seems that there were several bog-holes scattered about the place, each, perhaps, 25 to 40 feet in diameter. They have a few inches of water and several feet of rich muck, and are the resort of numerous frogs, turtles, and snakes. Last July Mr. Redevaty, thinking

that the muck would be an excellent thing to spread on his land, set one of his men at work hauling it out. While employed in digging, his spade brought up a number of arrow-points. He described them to be nicely piled side by side, edgewise, in two or three rows. There were perhaps two or three hundred in all. On each side and on top were some charred logs and sticks, that seemed to be the remains of an old fire. They were 10 or 15 inches below the surface of the pond. They are of a blue jaspery flint, and seem to be in an unfinished condition. I thought that probably the Indians had brought them from a distance (as I have never found any of the same rock anywhere in this neighborhood) and made this pocket and covered the traces of them by building a fire, intending to return and finish them at their leisure; or, perhaps, they hid them there to prevent their capture by their enemies.

STONE CELTS IN THE WEST INDIES AND IN AFRICA.

(Extract from a letter of Geo. J. Gibbs, esq., Turks Island.)

Mr. Gibbs draws attention to a paragraph (vol. ii, p. 451) in the work of Martin Fernandez Navarrete, a French translation of which was published in Paris in 1828, entitled "Relations des Quatre Voyages entrepris par Christophe Colombe, &c.," in which the natives of all the West Indies are said to use "des haches et des erminettes faites avec des pierres si élégantes et si bien travaillées, qu'on ne peut trop s'étonner de ce qu'ils ont pu les fabriquer sans fer." On page 448, vol ii, M. Navarrete repeats the words of Columbus concerning the idolatry of the natives, "Car dans leur maisons ils ont des idoles de plusieurs espèces. Je (Columbus) leur ai demandé ce que c'etait, et ils m'ont répondu que c'etait une chose de *Turey*, ce qui veut dire du ciel."

In the same letter, Mr. Gibbs, after drawing attention to several places in Livingstone's "Last Journal," where the distinguished author denies ever having heard of stone implements in Africa (pp. 83, 89, 442, 448), says that in 1841 a Spanish slave-ship was wrecked on the Caicos Islands. In conversation with Mr. Gibbs, who showed some of the negroes a stone celt, they remarked that such things were worshiped in their country, that they fall from heaven during thunderstorms, and that they are a sure preventive of the evil effects of lightning to those who keep them in their houses. It is esteemed very unlucky to part with one under any circumstances.

THE INDIANS OF PERU.

By F. L. Galt, M. D., *of Lynchburg, Va.*

The tribes of South American Indians who live on and to the eastward of the Andes in Peru belong, according to d'Orbigny's classification, to the *Race Ando-Peruvienne*, one branch of which he designates as

the *Quichuas* and *Aymaras*, and the other as the *Amtisian*. The latter, more especially, embrace those living to the eastward of the Cordilleras, whose home is among the lowlands, which, I suppose, include what is known as the "Montaña" of Peru. This Montaña embraces a district from an elevation of 4,000 feet down to the level of the Ucayali basin, whose average level above the sea varies from 200 to 500 feet, and is continuous with the lowlands of the Brazilian portion of the Amazon Valley. There are three platforms, differing greatly in height, which form the basins of the Ucayali, the Huallaga, and the proper main current of the Marañon itself; and the tribes who inhabit the low countries of Eastern Peru have traded for centuries among the broad currents of the first two river bottoms. The Ucayali River, which seems for some reasons worthy of being more properly considered the continuation of the Peruvian part of the Amazon, has a length of 885 miles from its debouchment into the Marañon to the point where the two streams Urabamba and Tambo unite to form it. On the old charts of the priests it was called the *Apo-Paro*, and the term Ucayali only applied to the more northern half, from about the Pachitea to the Marañon. A fine stream like this, which by recent surveys has been shown to be navigable for steamers its whole length, and with its comparatively moderate current of 2.65 miles per hour, must have naturally attracted the natives to its borders, where abundance of fish, turtle, and waterfowl offered so easy a livelihood. We accordingly find that the manuscript records of the friars of the order of Saint Francis, which show the ardent spirit of these enthusiasts during two centuries, mention numerous peoples dwelling along the whole length of this noble river; and the present deserted spectacle of its borders gives us no index of the population which once dwelt here. Another attraction for the native was the comparatively moderate heat which is to be encountered here, as in all parts of the Montaña of Peru, not rising above an annual average of 24° C., and it must have attracted migration now and then from the more desolate or cold heights of the sierras to the westward. The great drawback to the basin of this river Ucayali, and also to the whole of the river country of the lower part known as the "Pampa del Sacramento," would have been, probably, the inundations of the rainy season, and the comparatively few points suitable for permanent settlement. The simplicity of house structure, and the very few articles to be transported, would have counteracted this objection, and the generosity of the climate as to vegetable production would offer them a relief from the toil of a hardy agriculture and the preparation for cold, which they found so necessary among the mountains.

Of the origin of the tribes living in the lower portion of the Montaña of Peru, we have little or no reliable information. What relation the present representatives bore to the Inca population is uncertain.

In some recent surveys, undertaken under the auspices of Peru, of the tributaries of the Amazon, which waters the territory of that republic,

I had, as surgeon of the expedition, many opportunities of becoming acquainted with the tribes who live in the lowlands of the basin of the Ucayali, the Marañon, Pachitea, and other streams, and I could obtain but the faintest knowledge of their peoples. Tradition among them seemed to be reduced to its lowest condition, and among those tribes which I visited there was only one which seemed to treasure any notion of the Inca history; and they, in their pride of fancied descent from that race, showed in their physical type some resemblance to the ancient rulers of Peru.

Beginning at the mouth of the Ucayali River, the following tribes appear as we go up that stream: Kokamas occupying both sides and the adjacent country of the Marañon River. They are a Christianized people, and are those more frequently found about the villages occupied by the white settlers. Their color is darker than that of most others of the inhabitants of that country, and their stature is below the average. Their limbs have not the rounded forms which characterize some others, and their features are harsher in expression. They are very tractable and work faithfully. Fidelity among their women is a characteristic virtue.

The Mayourunas inhabit the country back from the river hereabouts, and are less approachable by Christian or civilizing influences.

Remains of the Setibos shipibos are here and there to be found, although, as is generally the case on this and other river borders of the Montaña, the tribal type is so destroyed by the custom of the priests for many years to collect together at the various missions the younger of the different tribes for religious and other purposes, that intermingling of blood has destroyed among most of the tribes distinctive marks.

The Conibos, are the largest, most numerous, and most important of all the river tribes, and, having been about the prominent missions, such as Sarayacu, Callina, and other places for many generations, they are the most conspicuous on the Ucayali. In their type they resemble much the Inca caste in their strongly aquiline nose, which is prominent; their broad forehead, large eye, yellow cornea, and not prominent cheekbone. The limbs are round; abdomen protuberant; hands and feet small; shoulders broad, though rounded. The custom of flattening the heads, said by some to be a custom among them, must be very rare, as I never saw an instance of it, though much among that tribe. They pride themselves much on their blood, and do not permit of marriage among neighboring tribes, although they frequently make raids on their neighbors living up on the Pachitea and Sungaruyacu, the Coxibos, for the purpose of stealing children, women, and slaves.

About the missions of Calleria and Caxiboya are found the remains of the older tribe of the Remos, who have disappeared very much through wars and disease. They, like the Amahuacas, who live higher up the Ucayali, above the Pachitea, are mostly to be found as slaves.

M. Castelnau, in his Voyage, gives some statements going to show that there is among the tribes of this region a definite idea of futurity in connection with the soul's immortality and of a Supreme Being. It appears to me that he must have confounded the notions they have gained by long contact with the friars with their original ideas. Those whom I often conversed with among these tribes, traders, priests, half-breeds, and Indians themselves, seemed, as far as I could learn, a race most ignorant of everything beyond the daily life they led, except where they had some comprehension of what they had heard from the teachings of the friars, who for over a hundred years have been among them. I was repeatedly told by the very intelligent prefect of the order of Saint Francis, at Caxiboya, the headquarters of the missions, that he had never been able to detect among the purely savage natures any notions of the subjects referred to, except that they seemed to have a vague idea of an evil spirit, whom they looked upon as the author of all the ills of life; that of the soul and its immortality they did not entertain the rudest conception.

The Conibo tribe, from their prominence on the river, are more approachable by the whites, and they show a larger degree of thriftiness and comprehension of the uses of trade. But when at their homes, unexcited by the animation of business, there seems little difference between them and the other tribes in that country, being indisposed to communicate information, quiet, with a species of sadness, or rather apathy arising from want of thought. Yet it is well known that when they, or any of the representatives of the tribes, are taken young, as is frequently the case—sale of them being one of the elements of trade on the rivers—and brought down to the villages on the Marañon, or to the interior, where there are white populations, they develop rapidly a remarkable sprightliness. They learn the Spanish language with great facility, as also the various duties they are called on to perform as nurses or servants for children or grown people, and in all respects acquire the arts of the stage of civilization of that country with ease. Many of these young persons, however, die before they have been in their new homes any length of time, not from homesickness, which they rarely feel, but from a change of diet and mode of life, the comparative plenty of their new mode of existence and its excitement apparently producing derangements of digestion. Among all the young people of the tribes of the Ucayali and its tributaries who thus find their way into civilization, the children of the Campas tribe, who inhabit the country of the Cerro de la Sal and the south part of the Pampa del Sacramento, are preferred on account of their quickness, energy, and fine physique, which, though slight, is somewhat more elegant in figure.

The Conibo tribe control the Ucayali for some distance above the Pachitea, and are then replaced near the Urubamba and Tambo Rivers by the Pirros, who are the most stalwart of all the aborigines of this country. They inhabit both sides of the Ucayali near the two rivers mentioned,

and also about the mouths of the Urubamba and Tambo. This change from the dull, heavy-looking Conibo, Sitibo, and Shipibo is possibly owing to a modification in climate, which, about the country of the Pirros tribe, is much more moderate as to temperature and dampness.

The surface of the country is also much more open a little way from the river margins, and allows, therefore, of locomotion by other means than that of the sluggish canoe. This difference of physical features of a section must in the course of time make considerable difference in the physique of races, and its effects are probably not more distinctive anywhere than in the tangled jungles of the Amazon and the open plains of the La Plata basin. This physical distinction reacts on the morale of the inhabitant, and substitutes for the sluggish, apathetic, and uncommunicative native of the former location the active horseman, the bold antagonist, and the ready occupant of the pampas of the temperate regions to the south. The country inhabited by the Pirros tribe communicates with the headwaters of some of the Brazilian rivers, and intercourse is more or less regularly kept up with the tribes of that country, inducing similarity of customs, &c. The Pirros also communicate with the country of Cuzco for trading purposes, and they show a much greater vitality than those living down on the Lower Ucayali. But, of all the tribes of the tributaries of the Ucayali, those of the Tambo and Ere Rivers and of the Cerro de la Sal, attract more attention by their long, persistent, and dangerous hostility to the whites. They are known in the old manuscripts as the "Antis," and under the name of Campas appear more conspicuously about the end of the last century. The friars of Saint Francis seem to have made, among the tribes of the Cerro de la Sal, greater progress in civilizing than elsewhere in the Montaña, and, from that portion of the valley of the Chanchamayo, of the Perene and Ere Rivers, they steadily pushed their way to the Ucayali, and even down to the Marañon, during the last century But it appears that an apostate from Christianity, one of the race who had been educated in Spain, returned to the land of his fathers, proclaimed himself as sent of God, to redeem his people from the tyranny of the worship of the priests, and a general massacre of these holy pioneers forever put a stop to progress in the southwest part of the Pampa del Sacramento. Since that time the route to the Ucayali by the Ere and Perene has been closed to the white man and the neighbor Indians; and even government expeditions sent to reopen that road have been baffled and compelled to retire before the ambuscades which the Campas ever prepared for all who sought to disturb their water-front along the Cerro de la Sal. Besides the Campas, living along these rivers there were the Campantis, Pirros, and Siminchis, although all were merged or lost in the towering reputation of the Campas, and now, all along the Ucayali, the Pachitea, and, in fact, all the streams flowing from the Pampa del Sacramento, that name is sufficient to startle a tribe into

fear or flight. The old name of "Enim" is to be found as that of an Indian sovereignty in the southern part of the Pampa, although one does not hear of it nowadays. The Campas have generally a broader chest than is common with the other tribes, proportionate to the height, and their hands and feet are often very beautiful as to size, and the instep of the foot much arched; their eyes are smaller than those of many other tribes found in the Ucayali Valley, and the forehead has not that breadth so common among the Conibos. The progress first made among them by the friars has had the effect of causing a good many reports as to their advance in the mechanic arts, and I heard, while upon the Ere and Tambo Rivers, that they knew now the art of working in iron, although I could never ascertain this fact from those whom I saw of that tribe. Being the Ishmaelites of the Ucayali basin, there was little to be learned of them from their neighbors.

Many of the tribal names mentioned by the friars in their early voyages down the Ucayali are not now to be heard on that river. Some have disappeared by war, others by pestilence, and some have left for "parts unknown." The old "Pano" lives now only as a sort of basis for some of the dialects, especially the Remo, Conibo, Sipibo, and Setibo. The language of the old "Omaguas" tribe, which now is rarely heard, is, I am told, the most difficult of all to learn; that one has to learn, in fact, two dialects, the men using one set of words to express their ideas, and the women another. In a modified form this is seen not only in the Quichua, but some other of the river dialects of the Upper Amazon.

During my visit to the river country of the Pampa del Sacramento I was unable to learn any traditions as to the Inca power having, in ancient times, ever extended itself as far east as that portion of Peru. However, in June, 1873, during an expedition made up the Pachitea and Pichis Rivers, which flow through the middle and southwest of the Pampa, I discerned, some 50 miles up the first-named stream, on the face of a sandstone rock which formed a surface some 60 yards long by 40 in height, near the foot of which flows the river itself, a great number of representations cut into the rock, and which could also be discovered by digging away the soil which had accumulated at the foot of this stony rampart. Some of them have a relation with other relics found in the interior districts of Peru. The Indians whom we had with us had never heard of or seen these tracings before, although they had, at least a few of them, gone up higher than this point, and lived near the mouth of the Pachitea River itself.

It is a very noticeable fact that these tribes of the lower platforms of the Montaña of Peru, and of its continuation into Brazilian territory, do not seem to be an aboriginal race, or one suited to their habitat. They remind one of refugees from some other clime, and have the appearance, as to the conquest they make over the difficulties of their situation, of "strangers in a strange land." The ease and frequency with which they move from one part of the river to the other, according to the stage

of water, the unhomelike look of their habitations, the untilled nature of the soil, where vegetation crowds up to the very doors, the unoccupied character of their life, their inability to tell us of themselves, their forefathers, of the scenes of the land they live in, all go to show a foreign extraction of not many centuries past. In fact some of the tribes living now on the Ucayali and on the Marañon did come from the slopes of the Andes far away to the northward in Ecuador, and others arrived there from the upper country about the Huallaga, and Upper Marañon; while the name "Omaguas," which appears on the Marañon in the name of an abandoned village site, and a member of which tribe rarely is heard of in this western part of the great Amazon Valley, comes from the south and east under the name of Tupi or Guarani. The physical characteristics applied to this stock by La Condamine will answer for many of the tribes encountered in this section of South America. It seems not improbable that the oldest of the tribes living some few centuries back in the low country of the Ucayali and Marañon have been replaced by the stronger red races from the Andean slopes, who in their turn have withered under the influence of their new climate and its debilitating tendencies. To this cause for disappearance must be added small pox as a large factor. During the past year this scourge has desolated the river country of the borders of the Brazilian and Peruvian frontier, and has caused the entire disappearance of one of the most docile and physically the handsomest of the tribes about the mouth of the Napo, the Yaguas, who died by families, and were eaten by the wild beasts and birds of the forest about them. The custom of piercing the lower lips and the ears for the purpose of placing wooden plugs therein, which was characteristic of the old Tupinamba race of Brazil, is to be found now and then among some of the tribes of the Ucayali and the Napo, on which latter stream the enormous dilatation of the lobe of the ear by these plates is a striking peculiarity among one of the tribes known as the Cotos. But as far as I could learn there seems to have been given to none of the Ucayali or Marañon tribes that organized faith in religious matters which some writers have discovered among the traditions of the Tupinambas of Brazil.

In reference to the breadth of chest and size of the lung-case noticed among the dwellers on the Andean slopes, I may state as the result of my own observation that this development is oftener to be encountered among the mixed breeds, the cross of the Indian and white, and more particularly in the female, than among the pure-blooded Indians whom I have seen from there; and I am disposed to ascribe this to the fact that the female is the burden-carrier not only among the pure Indian races, but also among the half-castes of Peru, and in her relations with the whites has more drudgery of life to perform in many instances. The custom among them of carrying burdens on the head, while it contributes to expansion of the chest, gives them an erectness and elegance of movement of the body which is frequently noticed. The absence among the

Indians of the Pampa del Sacramento and adjoining regions of the muscular delineation in the limbs is very characteristic; they seem to be cushioned with adipose matter, which gives a roundness which does not disappear even when performing an act of muscular exertion, and the contrast between this race and the negro of Brazil is very striking. This roundness of figure is continued in the mixed breeds of Indian and white. One of the most frequent and severely painful affections among the Indian races is what is known as "cold abscesses" which form in and under the muscular tissue of the body. They give rise to enormous deposits of pus, which entail great debility on the individual, and which are these adipose tissues breaking down, no doubt, under influences of depressed vitality. This softness of the muscular system is also noticed in their hands, which, although in incessant use of the paddle, never seem to acquire that horny hardness to be found among a laboring class in more open and temperate regions. In the tribes living on the Marañon borders, about the Ucayali mouth, the nose has a tendency to spread considerably at the nostril, nor has it the arched appearance to be seen among the Conibos and others living higher up on the Ucayali River. The color of the skin, too, is more inclined to brown than red, and the prominence of the cheek-bones is greater. A noteworthy fact among the half-breeds—the offspring of the Spanish-Peruvian descendant and the Indian of the Montaña of Peru—is the great general resemblance there is to the Chinese type, so much so as to make us often doubt whether there may not be sometimes a blood kinship. This resemblance is found in the oblique position of the eye, the yellow-white complexion, and the shape of the nose. This resemblance is one of the most common features observed by strangers who are thrown among the half-castes of this region.

The different dialects spoken by the tribes on the Marañon, Ucayali, and Huallaga Rivers, where the Indians have been for some time in contact with the white or half white Hispano-American, are very much intermingled in conversation with the Spanish language, so that persons who are familiar with this latter are enabled sometimes to partially understand the subject when listening to the natives. The Mestizos who talk with the natives always use the Spanish largely in their sentences. I was also told that the *Quichua* spoken in that part of Peru was much corrupted, sometimes so much so as not to be intelligible to those speaking the purer form in use about Cuzco.

SANTA ROSA ISLAND.

By Rev. Stephen Bowers.*

The approximate geographical position of the central portion of this island is latitude 33° 55′ north and longitude 120° 8½′ west. The island is fifteen miles long by ten miles in width, the general shape being that of a parallelogram, and contains about 75,000 acres. Its longer axis is parallel with the line of the coast and the Santa Inez Mountains, which form the northern side of Santa Barbara Channel. The channel between Santa Rosa Island and the island of Santa Cruz has a width of five miles, and that between Santa Rosa and San Miguel a width of four miles. The depth of water around Santa Rosa Island is less than that of the other islands. The outline of the island is bold, and no harbor exists around its shores. There are, however, several places where vessels can land, and the present proprietors, the Messrs. Moore Brothers, have built a wharf on the eastern end of the island, where vessels can load and unload at any time, except when gales prevail from the northeast.

Geology.—This island has been described as being composed of sandstone, but the first thing we observed upon landing was that the eastern end of the island is composed principally of volcanic rocks. At the wharf we found a good exposure of strata, forming cliffs about 30 feet in height, the lower portion, for about 15 feet above the sand of the beach, composed of stratified sandstone, fine grained, and destitute of fossils, with an occasional stratum of breccia or conglomerate. These strata have a dip of from 12° to 14° southeast. The upper portion of the cliffs consists of a horizontal deposit of fragments of rhyolite, trachyte, vesicular basalt, and white bituminous slate. The fragments gradually decrease in size from the bottom upward, and are cemented together with volcanic sand. The whole is covered with a deep and apparently good soil. In some places the rock fragments in the upper half of the cliffs have been water-worn and form conglomerate. This character of rock extends from the wharf southeasterly to near a sand-point at the southeastern extremity of the island, where it culminates in a hill of volcanic rock 175 feet high. This is exposed for some distance in a southerly direction from the beach on the north side of the point. The rocks have a tendency to weather into odd and fantastic forms, the angular ones becoming rounded by disintegration, irregular cavities and caves being worn in it by the winds.

*Dr. Lorenzo G. Yates, of Centreville, Cal., rendered me valuable assistance in the exploration of this island. The geology is principally compiled from his notes.

At the northeastern extremity the rock is a coarse, volcanic breccia, composed of porphyritic and trappean rocks, having a distinct stratification, with a dip of 30° southeast. Several spurs extend out some distance from the shore-line and others have been worn away by the incessant beating of the surf until they form small rocky islets, while the porphyritic rocks which have weathered out of the main body of the breccia, lie as smooth bowlders at the base of the cliffs. From this point the hills rise sharply to a height of from 250 to 300 feet, and run southwesterly to the main backbone of the island, which lies on the line of its longer axis. The highest points on this range were visited, and the altitude was found to approximate 1,400 feet. Several high peaks are grouped together about five miles south of the wharf, being on the southern side of the line of the longer axis of the island. Three of these high peaks, lying within a circuit of about two miles, were measured. The first (Black Mountain) measured 1,325 feet. Crossing over a depression 350 feet below the first summit, rhyolite and white bituminous slate occurs. The next peak south (Saddle Mountain) is about 100 feet higher than the first. Between this point and the hills on the southeasterly side of the Cañada la Cruz limestone occurs in the bed of the creek, with *ostrea titans* and other Miocene fossils. Southeasterly from Saddle Mountain, and lying between Cañada la Cruz and the ocean, there is an intrusion of syenite, the extent of which we did not ascertain; nor did we discover the line of juncture between the Miocene and Pliocene.

On the north side of the island, about ten miles from the wharf, and near the mouth of Soledad Cañon, there is a fine exposure of strata, consisting of about 90 feet of Post Pliocene deposit, containing fossil bones of vertebrates, and at one place fossil physas, at a depth of some 75 feet below the surface. This deposit is horizontal and overlies strata of older rocks, probably Pliocene, which dip 13° northeast, and contain *Pectens* and *Turbinellas* in abundance. From this point to the northwestern extremity, and around the west end of the island to the point where the main range of mountains meets the ocean, the shifting sands have covered the rocks, obliterating all other writings of time in the geologic formation.

History.—The first written account of this island and its inhabitants is that of Juan Rodriguez de Cabrillo, a Portuguese navigator in the employ of Spain. He reached this group of islands October 7, 1542, and spent nearly six months here and on the main-land. He died here and was buried on one of the islands on the south side of Santa Barbara Channel, most probably San Miguel.

Cabrillo describes Santa Rosa Island as filled with inhabitants, who differed in some respects from those living on the main-land, and spoke a different language. The women were comparatively white, very handsome, and of retiring and modest demeanor.

The cause of the decline and final extinction of this race is variously

stated. The old Jesuits of Santa Barbara Mission informed Mr. Taylor that a century ago the Russians were in the habit of visiting this island for the fur of the sea-otter, then very abundant here. They brought with them natives from Alaska, whom they left on the island during the winter months, having taught them the use of fire-arms. These fellows, in the absence of the Russian ships, amused themselves in shooting the defenseless inhabitants. Mr. Taylor thought that in this way we can account for the number of skeletons which lie exposed in different portions of the island. Another account is that the Russians themselves killed them off in vast numbers in order to obtain the furs they had accumulated.

Still another account is to the effect that a destructive famine prevailed, reducing the number from many thousands to a few score of individuals.

In examining their burying-places we found many skulls which had been broken by violence, but none that seemed to have been penetrated by bullets. This was especially true of those buried just beneath the surface. But as other tribes inhabited adjoining islands, they were probably sometimes engaged in war, which may account for the perforated and fractured skulls. A famine of food could hardly occur, as the inhabitants depended largely on the sea to yield them food. Mollusks are still abundant, as well as whales, sea-lions, seals, and sea-otters; also various kinds of fish and water-fowl. The only possible chance for a famine, we can see, would be in the drying up of the springs and fresh-water streams, now abundant in the island. In a large burying-place in the western portion of the island we found human bones occurring near the surface, which were broken lengthwise, as if to extract the marrow; and in the same place we found the skeletons of as many as fifty children, who would probably be the first to die in case of a famine. The stumps and roots of many trees, indicating about the same age, may be still seen in various portions of the island, and dead land-shells (*Helix ayersiana*) in multiplied millions, all of which must have been destroyed by a long drought many years ago. At all events, about the year 1816 the inhabitants of this island were reduced to a few individuals, and were removed by the priests of the Romish missions to the main-land. They were placed in the mission of the Purissima, in the western part of what is now Santa Barbara County. One individual, an old man, and the last survivor of his tribe, was visited by Dr. J. L. Ord a few years since. This man's name was Omsett, and he said his tribe was called Chumas. When visited by the doctor (to whom I am indebted for the old man's narrative respecting his people), through very old and entirely blind, he was quite intelligent, and spoke Spanish fluently. He represented his tribe as being very numerous previous to the advent of the Spaniards. They were strong, well-built, good swimmers, and fine fishermen. They made their hooks from the shell of the *haliotis;* had canoes made from the skins of sea-lions, and

also from the pine and large redwood logs found on the beach; used spears in killing the whale, the blubber of which they ate raw. According to this old Indian's account, their idea of a future state was somewhat obscure. They worshiped the sun, the crow, and the sword-fish. The sun they worshiped morning and evening, and as the source of light and heat. The sword-fish was worshiped because it brought them the whale, as they were numerous, and united with the "orca," or killer, in killing or driving these monsters ashore. Their object in worshiping the crow is not so clear.

Nearly all their food they ate raw, it being principally of fish and mollusks. They pitched their boats with asphaltum. They carried on considerable trade in shells with the Indians in the interior, who would manufacture them into money, and ornaments that were highly prized by both sexes, especially the females. The language spoken by the "Chumas" was different from that spoken on the main-land.

Antiquities.—A large portion of this island appears as a vast rancheria, and it once doubtless supported a vast population. Just west of the wharf a rancheria begins and extends for the distance of two miles, stretching across a point of land which projects into the sea. This old village or rancheria has an average width of about one mile. The sand has drifted over it in many places, and in others the soil has been removed by westerly winds until many skeletons are exposed, and human bones are scattered promiscuously over the surface. Some idea may be formed of this extensive shell-heap when I state that over the entire rancheria shells, bones, and other kitchen *débris* have accumulated to the depth of several feet.

Owing to the luxurious vegetation, the burial places were not readily found, but those examined yielded many skeletons. The implements were not numerous, and were generally broken when buried. The inhabitants seem to have been an indigent race, living in much greater poverty than those on the main-land. Including fossils and some alcoholic specimens, we obtained about one ton of specimens.

The specimens from the graves and shell-heaps consisted of mortars manufactured from sandstone; one *olla* carved from crystallized talc and used for cooking purposes; one pipe, cone-shaped, and about six inches long, with bone mouth-piece inserted in the smaller end; pestles of sandstone; perforated disks from the size of a silver half-dollar to five or six inches in diameter. These were used in games. It required either three or four to play a game with these disks. Two individuals, standing at a given distance, rolled the disk rapidly upon the ground between them, while one or two others stood at the side with sharpened sticks and caught the disks as they were whirled rapidly by. We also found a conical disk, which was probably used in spinning. Spear-points, arrow-heads, knives, drills, &c., of chert were common. We found wampum, beads, and a great variety of ornaments manufactured from shells. The *Olivella biplicata* is used from which to manufacture wam-

pum, the *Pachydesma crassatelloides* for beads, and the *Haliotis* for ornaments. The specimens in bone were principally whistles, perforators, needles, &c. We found a bone implement some eighteen inches long and shaped like a butcher's cleaver; also bone swords or spears.

Although more than sixty years have elapsed since the last survivors left this island, yet the material of which their houses were constructed remains undecayed. A circular excavation was made to the depth of three or four feet, around which the ribs of whales were planted pointing inward at the top, and covered with "sea-grass." Those we examined had fallen inward, and the bones and grass were covered with *débris* to the depth of a foot or more, but perfectly preserved. In many instances they had used the circular depressions, where these dwellings had been erected, for burial places.

It was not unusual to find the teeth very irregularly set in the jaw, and sometimes an extra tooth would appear. This probably gave rise to the story of skulls having been found on this island with double rows of teeth. I have frequently heard this related of the Indians that once inhabited this island and the main-land, but after exhuming some 5,000 skeletons, during eight or nine months' explorations in this portion of California, I failed to meet with a single case of the kind, nor have I been able to learn of a well-authenticated instance of such a find. In some instances the skulls indicated great longevity. The bones were generally large, and the markings of the muscular attachments indicating a very stout race of people.

NOTES ON THE HISTORY AND CLIMATE OF NEW MEXICO.

By Dr. Thos. A. McParlin, *Surgeon, United States Army.*
(Communicated by General J. K. Barnes, Surgeon-General, United States Army.)

HISTORY OF NEW MEXICO.

What is now known as New Mexico has had a varied history. First, the home of nomadic Indians, perhaps as peaceable, loving, and tractable as those first described by Columbus. Gold and silver and the quest of precious jewels, like the Golden Fleece, brought over the Spaniards, and with them Mother Church. In 1540 Francisco Vasquez Coronado came to the country with an expedition. He found some of the Indians nomadic, and others living in settlements, and among them he describes Cicuyé, extending along the river for six miles, and the soil cultivated by the Indians, from the mountains as far west as the present town of Agua Fria. This pueblo and cultivated valley correspond with what was afterward named after the patron saint, San Francisco de Asis de Santa Fé. As it is at least four hundred years old as a town, (how much older it may be there are no means of determining,) it is much older than San Augustine, Fla., founded in 1565, or any other town on this continent.

In 1546, during the empire of Charles V, it was determined to encourage the settlement of the Indians in towns in order to protect the Pueblo Indians. New Mexican Pueblo traditions accredit Montezuma with having gone south from this Territory, and with his people the substantial evidences of gold and precious minerals gave the Mexicans and their conquerors, under Cortez, the information that their gold came from the north, and with precious minerals existed here in great quantities.

The Indians were compelled by the Spaniards of this country to dig the mines in all parts of the Territory, to carry water, and pack ores and fuel on their backs to the furnaces; and in consequence, after the rebellion in 1680, when they drove the Spaniards out, they filled up and carefully concealed all evidences and traces of the mines they had worked so successfully. When in 1704 the Spaniards revisited New Mexico, the Pueblos entered into a compromise "by which the Spaniards were permitted to return, but with the positive and express condition that they should not open the mines or prosecute mining as a pursuit."

Hence it is probable that the richest mines in this country are yet to be discovered; and it is certain that but for the scarcity of water very many now known, but only imperfectly worked, would be very productive. The records of the ancient mine near Abiquiu, derived from an

old church near by, show that 10 per cent. in tithes collected from it amounted to $10,000,000. No mining of any extent has been prosecuted in this mine since 1680. Gold, silver, and coal and turquoise are found near Santa Fé; and from this country an unusually large and valuable turquoise was sent to the Emperor.

Pedro de Reralto was governor in 1600; in 1640 General Arguello was governor and captain-general, resident at Santa Fé as the capital; General Concha, in 1650; Henrique de Abila y Pacheco, in 1656; Juan Francisco Junio, in 1675; Antonic de Otermin, in 1680–'83.

The Indians rebelled first in 1583 and again in 1680, and on the night of the 20th August, 1680, Otermin evacuated the place and marched to El Paso, arriving there October 1.

In 1681 the viceroy at Mexico dispatched General Otermin from El Paso with an army to recapture the capital; but after reaching La Bajada, 21 miles from Santa Fé, he gave up the enterprise, finding the Pueblos concentrated to resist him. In 1692 the viceroy commissioned Diego de Vargas Zapata Lujan Ponce de Leon as governor and captain-general of New Mexico, who fought and overcame the Pueblos September 13 of that year and entered into Santa Fé. After the re-establishment of Spanish supremacy he returned to El Paso, reaching there December 20, 1692, and returned December 16, 1693, to Santa Fé, where his occupation and re-entry was disputed, and a battle was fought on Christmas-day. The next day he took formal possession of Santa Fé, in the name of King Charles II.

After the reconquest by the Spaniards, the Pueblos (twelve towns on the Rio Grande or in the vicinity) made their submission and were subject until 1837, when they rebelled, on account of a tax on tobacco and other articles laid by Governor Albino Perez. After fighting a battle with the Pueblos at Santa Cruz de la Canada, he was beaten, returned to the suburbs of Santa Fé, where he was overtaken and assassinated, August 9, 1837.

In 1838, Manuel Armijo was recognized as governor, and continued so until the capital was taken possession of, in the name of the United States, by General Stephen W. J. Kearney, U. S. A., August 18, 1846. General Kearney occupied the palace, a building now in existence, and which was erected previous to the year 1581, being built then of material of the old Indian town, (Cicuyé.) Since his time it has been occupied successively by Col. John M. Washington, Col. John Monroe and Col. E. V. Sumner, as military governors, until March, 1851, when the existing territorial government was initiated.

The office of the Secretary of State contains several extended documents, in Spanish, upon the history of the conquest, occupation and reconquest of the country. From these and the works written upon New Mexico by Mr. Elias Brevoort, Gov. W. F. N. Arny, Mr. D. J. Miller, and General Davis, the student may find ample material for interesting inquiry.

CLIMATOLOGY.

Formerly a journey across the plains, a distance of 700 miles from the frontier of Missouri, requiring a life in the open air, traveling with a wagon-train, amid hostile Indians, from May to July, was necessary to reach Santa Fé. Many pulmonary invalids came out, living on game and buffalo-meat, gradually ascending day by day to the level of 8,000 feet in the Rocky Mountains. They were undoubtedly in the great majority of cases benefited, while many recovered from threatened consumption.

Two railroads now have advanced to within 220 miles of Santa Fé, at El Moro, near Trinidad, and it is expected that by May 1, 1877, the Denver and Rio Grande Railroad will be completed to Fort Garland, 156 miles from Santa Fé. The line of daily stages now runs from Santa Fé to El Moro in 36 hours.

Now the traveler passes over the plains on the railroad, and at once begins traversing the Raton Mountain chain and then the spurs of the Rocky Mountains. The old-fashioned trip across the plains is deprived of many advantages to the invalid above mentioned; although in some cases it is (especially to the timid valetudinarian) compensated by an earlier and more comfortable transit.

The altitude of Las Animas, (Fort Lyon,) 4,000 feet, and of Trinidad, 5,000 feet above the sea, has been quite beneficial to such as require a gradual approach to a higher level.

They are accessible by railroad, and comfortable accommodations are to be had at both places.

After reaching Fort Garland, nearly 8,000 feet above the sea, or Santa Fé, 6,846 feet, any less degree of elevation can be obtained by going southward down the valley of the Rio Grande toward El Paso, 3,600 feet of altitude; and at every step southward a milder summer climate will be found.

A portion of New Mexico, the Mesilla Valley, acquired in 1848 under the Gadsden treaty, has of late years developed features of unusual interest on account of its mines, minerals, pasturage, fertility and climate. It is between the thirty-third and thirty-first and a half parallels of latitude, is about 70 miles long, from 1 to 6 miles wide, and contains about 280 square miles; embracing the towns of Dona Ana, (population 1,000,) Las Cruces, (2,000,) Mesilla, (2,000,) and others of less size.

The air is mild, snow being very rarely seen, with a bright daily sunshine in about 360 days of the year. Vegetation dries rather than rots; meat is cured without salt in the open air; and it presents to the invalid the advantages of a very moderate altitude, varying from about 4,000 feet near the Rio Grande to about 7,000 feet in the high cattle-ranges of the Guadaloupe and other mountains. The valley is protected by the mountains from the cold winds prevailing from the north.

I know of one asthmatic patient who abandoned the Pacific coast to join a friend in Mesilla, who, similarly affected in every other locality,

had wanted him to join him. His friend had secured the desired climatic relief and taken up his residence there.

The dryness of the air in the Lower Rio Grande and Mesilla I have no doubt is not exaggerated. During the past year I had occasion to see the body of an individual who died on the southern plains (of starvation, it is said) several (perhaps seven) years ago. The body was found some time after death, and had been buried near Fort Craig. It was disinterred for removal to the national cemetery here in 1875, and presented a remarkable preservation by desiccation. The process it had undergone was what I would term mummification, and reminded me of the accounts of what occurs to the bodies of the dead when abandoned in the deserts of Lybia or Arabia.

The Mesilla Valley is said to produce a fine variety of grape, with juices heavier than from the grapes of Madeira and Portugal, as the grapes remain on the vine until they commence to dry before being pressed; and the wort contains as much sugar as the sweetest of Malaga, (Brevoort.) When dried, they make a good raisin. The almond-tree, peach, apple, pear, quince, apricot, are raised there, and all kinds of garden-plants; and probably game is as abundant as elsewhere in the country.

Mesilla may, I think, be considered a very favorable locality for pulmonary invalids. The trip across the plains and to New Mexico may be contrasted and compared with interest to the invalid with that which might be experienced in old Mexico. The journey from Vera Cruz to Mexico is made by rail in fifteen hours. The ascent is 7,459 feet, (to the highest point on the road 8,318 feet,) and is made in ten hours. "Many travelers, though in health, (says Prof. E. R. Peaslee,) experience a decided dyspnœa on reaching these altitudes, especially in making any considerable exertion, on account of the rarefaction of the atmosphere, though no amount of effort produces much sensible perspiration. The consequences in cases of pulmonary emphysema or asthma dependent upon cardiac affections are, as might be expected, not favorable. Asthma depending on derangement of the stomach, however, is sometimes cured. Chronic bronchitis also is not likely to be relieved at this altitude, combined with the dampness I have mentioned.*

But all these are alleviated by a residence at a lower altitude, the point suitable for such cases being found at Vera Cruz or between that city and the altitude of Cordova or Orizaba, *i. e.* 2,700 to 4,000 feet. (New York Medical Record, No. 286, April 29, 1876, p. 291.)

The situation of the Mexican peninsula between the Atlantic and Pacific Oceans, and the nearness of all its cities to one or other ocean, is very different, however, from that of the inland nature of New Mexico;

* The present city of Mexico was built upon grounds formerly covered by Lake Tezcuco, and into which it is drained. (See New York Medical Record, April 27, 1876 p. 290.)

and especially in the dryness of the atmosphere of our continent is the patient interested.

With all the dampness found at the city of Mexico, it is stated by Dr. Peaslee that "Phthisis is not indigenous in that city, and it is not seldom arrested in those who come here from the north. A member of the Mexican Congress assured me that the natives do not die of phthisis, and that the lives of phthisical patients from the north are usually much prolonged by a permanent residence here." (*Ibid.*, p. 291.) He thinks, however, it presents no special advantage to phthisical or bronchitic patients, and he cannot recommend it to such as a winter residence.

But there are other places of lower altitude in this country (Mexico) which he believes to be fully equal, and in some respects even superior, to any of the famous resorts abroad, mentioning "Cordova (altitude 2,715 feet) and Orizaba, (4,030 feet,) both presenting a tropical climate and all its productions and the most grand and picturesque scenery. Cordova has, moreover, sometimes been visited by yellow fever. Jalapa also, now accessible by railroad, is doubtless equal to either of these places as a sanitarium for this class of patients, and as a residence is one of the most beautiful places on earth. Its *great humidity* may, however, render it unsuitable to some cases, and the sudden chill of the northers must also be guarded against in these places. But Cuernavaca, 60 miles south of Mexico and not accessible by railroad, has an altitude of 5,428 feet, and the same climate and productions as Orizaba, and is far more desirable. In addition to these, Tetecala, not far from Cuernavaca; Atlixco, 23 miles from Puebla, and Monterey, are mentioned by Dr. Peaslee, though the latter is only accessible by a tedious journey by diligence."

It may be interesting to compare with the climate of Mexico that of Colorado, Utah, New Mexico, and Texas. Whatever may be lost of the tropical air and productions as we go northward from Mexico may be more than made up by the dryness of the atmosphere, a short wet season, and diminished rain-fall.

In some localities dust-storms are sufficiently prevalent to be prejudicial, on account of the irritation they occasion to the air-passages. In Texas *the heat of summer is extreme*, and the sudden vicissitudes of temperature and moisture and extreme chill produced by northers are worse, perhaps, than in Mexico. In Utah (see Report of Surgeon E. P. Vollum, Circular No. 8, Surgeon-General's Office, May 1, 1875, p. 343) the humidity is marked in the spring months, arising from the winds passing over Great Salt Lake from the northward, bringing the watery vapors not only from that great body of water, but also from the regions beyond, supplied by the southwesterly currents that are seen to pass over at a great altitude most of the winter long. This statement is true as to the climate of Camp Douglas, 2½ miles east of Salt Lake City, and at an altitude of 4,904 feet above the sea.

"Great Salt Lake, with a shore-line, exclusive of offsets, of 291 miles, is vast enough to furnish a horizon in places like the ocean itself."

In Dr. Vollum's special report on the diseases of Utah, (*ibid.*, pp. 341–343,) he regards the altitude and climate of Utah on phthisis as favorable. * * "If a case comes here in the incipient stage, and is well situated for comforts, that it will get well spontaneously from the beneficial effects of this altitude and the inland dry character of the atmosphere. It is the boast of the people that this is not a consumptive country, which is my opinion decidedly. On the other hand, it is believed that if a patient comes here in the later stages of the disease, that the atmosphere is too rare to give the proper support, and that the case will be hastened to a termination more speedily than on the sea-coast. * * The beneficial influence of this climate on asthma is *decided* and deserves a *prominent mention.* It is also the boast of the people, as well as the physicians, that asthma cannot exist here, excepting under a relieved and modified condition; which I think is the case."

Very many invalids are attracted annually to the mineral-waters of Manitou, Colorado, (6,370 feet above the sea-level, and 8,000 below the summit of Pike's Peak,) where there are several springs containing carbonic acid and carbonate of soda, (as the Navajoe, Manitou, and Ute soda;) purging carbonated soda-waters, modified by the presence of sulphate of soda and potash, as the "Little Chief" and "Shoshone;" and ferruginous carbonated soda-waters containing carbonate of iron, as in the "Iron Ute" and the "Little Chief" mineral springs.

In a memoir (Saint Louis, 1875) on the climate of this region, by S. Edwin Solly, M. R. C. S., (late house surgeon to St. Thomas Hospital, London,) reference is made to the decrease of pressure in a rarefied atmosphere, causing a diminution of the gases of the blood and lymph, and this probably checks the advance of phthisis, as unquestionably beneficial in certain cases. In phthisis, where the weakness is not excessive but there is anæmia and want of assimilation, a high elevation with a moderate supply of stimulants and a course of cold douches is generally beneficial. The greater dryness of mountain air acts beneficially on phthisis, probably for the most part in the manner indicated by Dr. Herman Weber: "We may here mention that although the loss of moisture to the whole organism may not be greater in high than in low elevations, yet the acknowledged *greater loss through the lungs* may be accompanied by local effects in certain morbid conditions of the respiratory organs, as well as by producing a more active circulation in the lungs in order to supply the required moisture, as also by favoring a kind of *drying up of surface*, secreting a morbid amount of mucus and pus, and also of moist exudations within the tissue. Possibly the improvement in many cases of chronic catarrhal pneumonia may be produced by this increased afflux of blood and increased lóss of moisture."

"Very highly situated places are adapted for winter treatment (of phthisis) on account of the greater number of clear days." (Braun.) And for another reason they are specially desirable in the winter; because in high elevations there is less moisture during the winter than at

any other season of the year, and therefore the air being dry, the greater actual cold than in lower climates is felt less severely, and if the body is warmly clad the lowness of the temperature exerts only its tonic influence. The air being rarefied, the sun has a much greater influence, being more constantly visible in mountainous districts, and enables the enfeebled invalid to spend several hours almost daily in the sunshine with very great advantage. (Page 32, "Manitou, Colorado, U. S. A.; its mineral-waters and climate." Saint Louis, J. McKittrick & Co., 1875.)

Dr. Solly refers to the fact that oxygen is essential to procure change of substance, and as it diminishes in proportion to the elevation above sea-level, it might be supposed that healthy change of substance would be retarded in mountain air; "but this," he adds, "is practically found to be otherwise, and the reason doubtless is that, as only about 25 per cent. of oxygen is on an average used in respiration, there is probably more than sufficient oxygen at any height that has as yet been attained by man."

The discussion as to the gases of the blood, their ratio to other constituents, condition of the oxygen as free, mechanically dissolved therein, or chemically combined, or both, I have no disposition to continue; but in so far as atmospheric pressure may be considered an important cause of variation, we have the statement of Lehman (Physiological Chemistry, vol. 1, p. 572) that "Liebig is certainly in the right when he advances the proposition that 'a gas can only be considered as mechanically absorbed when its quantity increases and diminishes in proportion to the external pressure.'" We think we are justified in concluding with Liebig that the quantity of oxygen which may be absorbed by the blood is constant in amount, and, to a certain extent, independent of external pressure—an opinion which is based partly on the fact that the respiratory process is carried on nearly the same, both at very great heights and at the level of the sea; and that no more oxygen is absorbed, *even in an air very rich in oxygen*, than in the ordinary atmosphere." A certain amount of mechanical difficulty, labored respiration, on ascending heights rapidly is generally experienced. At the same time, the very great strain put upon the muscles of locomotion causes pain in the limbs. We have no reason to expect the muscles of respiration to bear undue exercise and strain without fatigue, and it very probably contributes largely to what is known as dyspnœa, which is experienced as severely after rapid running any distance upon a plain. The question might be asked to what extent a diminished atmospheric pressure might facilitate the escape of carbonic acid from the lungs? May it not be far more important to free the blood rapidly of its carbonic acid, which is poisonous, than to inhale and accumulate oxygen in excess of the need of the system and the chemical capacity of the blood to utilize?

The extent to which diminished pressure alone may affect respiration can best be determined by the aëronaut, who reaches a height without

physical fatigue. He does so, however, at a very rapid rate, and a quickened respiration is the result. Dyspnœa (besoin de respirer) results from any change of accustomed relations between the lungs and the air to be respired. It occurs in pregnancy; (in dropsical accumulations, abdominal or thoracic, which obstruct the expansion of the chest and lungs, and limit the free play of the muscles of respiration and fatigue them.) Emotional disturbances, nervous perturbations, and mental anxiety cause it, as well as any undue physical labor or unwonted exertion.

That the respiration of an atmosphere of 8,000 feet above sea-level need not necessarily involve dyspnœa in an individual, I know from personal experience. I visited this country, ascending 8,000 feet, in 1849, and lived at an elevation of between 6,700 and 7,000 feet for three years. Again, in the past year (1875) I revisited New Mexico, and I have never detected in myself any disturbance of respiration as the effect of this altitude—not even a quickened respiration. I am not unmindful of the fact, however, that another person may have a different experience, but it may, perhaps, be attributable to other causes than altitude, or as combined with it.

The amount of oxygen present available for respiration may be in some degree dependent upon the stagnation or relative movement of the air. A moveless atmosphere becomes very oppressive, and perhaps is most prevalent in low countries. The movement of the air is, as a rule, greater in the mountains and high altitudes generally. I invite attention in this connection to the Chief Signal-Officer's remarks for October, 1874, (page 285, report for 1875:) "The extreme maximum movements of the wind have been, at Breckenridge, 7,650 miles; at Cape Henry, 9,147; Cape May, 6,907; Cleveland, 7,281; Escanaba, Mich., 7,217; Long Branch, 9,242; Pike's Peak, 14,734; Sandy Hook, 10,917. The extreme minimum movements have been, at Memphis, 1,700, and at Shreveport, 1,886. The calm area is therefore coterminous with that of high pressure."

That high temperature produces oppression in breathing is evidenced in the East Indies both in the periods of calm and during the prevalence of the hot winds, especially when, as happens in midsummer, the thermometer reads higher at night than in the day-time. At Nowshera, in 1867, the condition of the troops is described as "gasping for breath. There was a peculiar feeling of weight on the chest, even in the apparently healthy; and after every 20 inspirations, or thereabout, a strong and convulsive effort was necessary to inflate the lungs. * * * When the cause, viz., prolonged high temperature, was removed, an almost instantaneous return to health (in cases of insolation) was the result." (British Army Med. Dept. Report for 1868, Appendix No. X, pp. 296, 297, by Asst. Surg. Staples, 19th Regt.)

"In the same way that we cannot endure either constant dryness or dampness, so we cannot endure a very constant state of the barometer without suffering in our breathing or nerves. In fact, there is little

doubt that rapid changes of the barometer are more favorable for the more important functions of life than its relative stability; and this probably explains in a measure the value of both mountain and sea air." It also explains the benefit experienced frequently by confirmed invalids in a change from inland to sea-shore, or from mountain to sea-level, or *vice versa*.

Dr. Holland, in his "Medical Notes and Reflections," expresses the opinion "that the action of different degrees of atmospheric pressure in disturbing the bodily functions and general health is rather derived from the frequency of fluctuation than from any state long continued either above or below the average standard; that of the two conditions, suddenly incurred, the human frame is *better capable of withstanding a rarefied* than a condensed atmosphere; and that, in either case, the previous health and proneness to disorder in particular organs are greatly concerned in determining the results on the body."

He supports some of these views from the fact that "there are inhabited places in America, such as the town of Potosi, at an elevation of more than 13,000 feet, the inhabitants of which seem to have tolerable health." (Medical Times and Gazette, London, September 9, 1876, p. 299.)

At all elevated places the diurnal variations, barometric and thermometric, are sufficiently great to meet the demands of the economy for change, and these are augmented agreeably, and changed again, with the months and seasons as they come. At the same time the extremes of temperature are not experienced in high as in low altitudes; certainly the mountains are devoid of the intense heat of other more northern but lower localities.

The annual range of the thermometer at some places otherwise favorable becomes too excessive to be compatible with health in weak constitutions. At some low places the long continuance of summer-heat debilitates so greatly that months pass before normal vigor is regained. Extreme heat of long continuance involves even fatal prostration in a very few hours when the action of the skin is suspended, (insolation;) and this may occur in localities where, in a few months, an almost Arctic rigor is experienced. We fail to find in the mountains such experiences or such results; on the contrary, the air is invigorating and bracing at all seasons under conditions that prevail elsewhere, and not involving extreme exposure.

The contrast is particularly noticeable in India between the low plains and the hill stations.

We find the Savoyard, the Swiss, and the residents of mountains generally, of our time, as hardy as the mountaineers of history. They do not degenerate at home, nor until they migrate to the lowlands. The inhabitants of Georgia, Circassia, and Cashmere, and the hill tribes of India are a superior race. The Arabs and Abyssinians on the elevated lands of the desert and on the sides of the mountains from which the

Nile descends present a striking superiority over the people of lower Egypt. Their fiery life, love of liberty, and warlike genius place them immeasurably above the "Fellahs." The recent war against the Abyssinians has demonstrated anew the vigor and valor of their race.

The human race has not only degenerated by dwelling in low, unhealthy places, but it is again and again decimated by the pestilences generated in them. In the language of Dr. Farr, "it is destroyed now periodically by five pestilences—cholera, remittent fever, yellow fever, glandular plague, and influenza. The origin or chief seat of the first is the Delta of the Ganges. Of the second, the African and other tropical coasts. Of the third, the low west coast around the Gulf of Mexico, or the Delta of the Mississippi, and the West India Islands. Of the fourth, the Delta of the Nile and the low sea-side of cities of the Mediterranean. Of the generating field of influenza nothing certain is known; but * * * the four great pestilential diseases—cholera, yellow fever, remittent fever, and plague—have this property in common: that they begin and are most fatal in low grounds; that their fatality diminishes in ascending the rivers and is inconsiderable around the river sources, except under such peculiar circumstances as are met with at Erzeroum, where the features of a marshy sea-side city are seen at the foot of the mountain chain of Ararat. Safety is found in flight to the hills."

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In treating upon the "salubrity of high places," he refers to the influence of locality on race, of the sanitary instinct, the effect of the high land, and the sight of the hills on the energies of the sick, the longevity of the inhabitants of various places, the effect of healthy places on the breed of animals, the degeneration of race in unhealthy places, the time required to produce degeneration and degradation of race.

It is, perhaps, well for us, as individuals, to revert to such historic facts as he presents in terms of classic elegance, and it is, I trust, cognate to the subject we have in hand. "As the power of the Egyptians descended from the Thebaid to Memphis, from Memphis to Sais, they gradually degenerated, notwithstanding the elevation of their towns above the high waters of the Nile, their hygienic laws and the hydrographical and other sanitary arrangements which made the country renowned, justly or unjustly, for its salubrity in the days of Heroditus, the poison of the Delta in every time of weakness and successful invasion gradually gained the ascendancy, and as the cities declined the canals and the embalmments of the dead were neglected, the plague gained ground. The people, subjugated by Persians, Greeks, Romans, Turks, Mamelukes, became what they have been for centuries, and what they are in the present day. Every race that settled in the Delta degenerated and was only sustained by immigration. So, likewise, the populations on the sites of all the city-states of antiquity, on the coast of Syria, Asia Minor, Africa, Italy, seated like the people of Rome on low ground under the ruin-clad hills of their ancestors, within reach of

fever and plague, are enervated and debased apparently beyond redemption.

"The history of the nations on the Mediterranean, on the plains of the Euphrates and the Tigris, the deltas of the Indus and Ganges, and the rivers of China, exhibit this great fact: The gradual descent of races from the highlands, their establishment on the coasts in cities sustained and refreshed for a season by immigration from the interior, their degradation in successive generations under the influence of the unhealthy earth, and their final ruin, effacement, or subjugation by new races of conquerors. The causes that destroy individual men lay cities waste, which, in their nature, are immortal, and silently undermine eternal empires.

"On the highlands men feel the lóftiest emotions. Every tradition places their origin there. The first nations worshipped there. High on the Indian Caucasus, on Olympus, and on other lofty mountains the Indians and the Greeks imagined the abodes of their highest gods, while they peopled the low underground regions, the grave-land of mortality, with infernal deities. Their myths have a deep signification. Man feels his immortality in the hills." (Page xciv, Report of William Farr, esq., to the Registrar-General of England. London, 1852.

The climate of Kansas, so far as my experience of it may warrant an opinion—and I have served there in 1849, 1857, 1858, 1873, 1874, 1875—is not favorable to pulmonary invalids. They should go out on the plains and gradually work their way to the mountains. Neither can I recommend Texas, unless it may be the region near San Antonio, which is said to be favorable. San Antonio is, however, liable to choleraic visitations, and, being a limestone region, the fatality is extreme. I have seen pulmonary invalids visit New Orleans and very rapidly decline, I suppose on account of the excessive humidity.

Of Colorado I have no experience. It resembles the climate of New Mexico, but is to the north of it, and may be inclement.

Of New Mexico there are certain features worthy of consideration by invalids and their advisers.

I. The dryness of the atmosphere associated with elevation above sea-level to be found at any elevation desired, in localities ranging from 3,600 to 8,000 feet.

The dryness of all mountain regions is acknowledged. The range of mountains in Colorado has this excellence in common with those of New Mexico.

By reference to the report of the Chief Signal-Officer of the Army for January, 1875, it will be perceived that the percentages of relative humidity for the different districts average as follows: New England, 73 per cent.; Middle Atlantic States, 74; South Atlantic States, 79; Gulf States, 82; Lower Lake region, 79; Upper Lake region, 70; Ohio Valley, Tennessee, and the Northwest, 73. As usual, the mean relative humidity has been lowest at the Rocky Mountain stations, amounting

to .56 at Denver and .51 at Santa Fé. In the report for July, 1874, p. 271, he remarks: "The relative humidity has averaged on the Gulf and South and East Atlantic States 75; New Jersey coast, 85; in the Lake region, 68; Lower Mississippi Valley, 70; in the Tennessee and the Ohio and Upper Mississippi Valleys, 62; in the Lower Missouri Valley, 58; at the Rocky Mountain stations, 41." I extract from his report as of interest the following data:

SANTA FÉ, N. MEX.

Maximum, August 2, 1874, 89° F.; minimum, February 24, 1875, 2° F.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
	°	°	°	°	°	°	°	°	°	°	°	°
Range	36	40	45	52	42	55	45	54	63	65	49	50
Monthly means	71.1	69.9	60.6	52.3	38.7	29.2	28.1	31.4	34.4	47.4	59.2	67.9
Rain-fall in inches	3.92	1.73	1.42	2.47	0.58	2.26	0.67	0.72	1.37	0.33	0.88	0.33

Rain-fall, annual amount, 16.68 inches.

DENVER, COLO.

Maximum, July 4, 1874, 102° F.; minimum, January 9, 1875, 29° F.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
	°	°	°	°	°	°	°	°	°	°	°	°
Range	51	45.3	57.4	70	64	76	84	67	72	69	52	59
Monthly means	76.1	73	59	52.9	42.2	29.7	16.8	32.3	33.4	44.5	60.2	70.4
Rain-fall in inches	3.33	0.68	1.34	0.64	0.08	0.17	3.38	0.60	0.39	2.24	1.94	0.43

Rain-fall, annual amount, 15.24 inches.

COLORADO SPRINGS, COLO.

Maximum, July 11, 1874, 98° F.; minimum, January 13, 1875, 25° F.
Maximum thermometer broken; rain-fall, annual amount 15.24 inches.

SALT LAKE CITY, UTAH.

Maximum, July 1, 2, and 3, 1874, 98° F.; minimum, January 16, 1875, 5° F.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
	°	°	°	°	°	°	°	°	°	°	°	°
Range	42	38	49	51	34	43	46	39	51	60	56	56
Monthly means	78.2	74.7	62.6	55.6	43.4	33	29.4	33.7	35.2	50.3	60.1	69.1
Rain-fall in inches	2.42	1.03	0.20	1.74	2.16	0.73	3.05	0.79	2.81	1.50	2.91	0.90

Rain-fall, annual amount, 20.24 inches.

SAN FRANCISCO, CAL.

Maximum, September 14, 1874, 89° F. Minimum, December 26, 1875, 40° F.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
Rain-fall in inches.....	0.00	0.00	0.02	2.69	7.53	0.33	8.01	0.32	1.36	0.10	0.22	1.02

Rain-fall, annual amount, 21.54 inches.

GALVESTON, TEX.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
Rain-fall in inches.....	9.31	7.19	6.84	0.12	1.58	6.92	4.31	2.94	3.51	2.55	1.50	0.89

Rain-fall, annual amount, 46.66 inches.

NEW ORLEANS, LA.

	1874.						1875.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
Rain-fall in inches.....	12.93	4.82	4.21		1.12	3.27	8.44	13.85	10.84	8.05	2.51	4.92

Rain-fall, annual amount, 74.98 inches.

He remarks for June, 1875, as to relative humidity: "This element averages 80 per cent. for the immediate coast of New Jersey and New England, and 75 per cent. on the South Atlantic coast. Elsewhere, over nearly the entire country east of the western plains, the average is from 65 to 70 per cent. It is, as usual, very low at the Rocky Mountain stations, being 33 per cent. at Cheyenne, 29 at Salt Lake City, and 28 at Denver."

The rain-fall in inches for June, 1875, was, for Santa Fé, 0.33; for Denver, 0.43; Salt Lake City, 0.90; and the annual amount of rain-fall for the same places is reported at 16.68, 15.24, and 20.24, respectively. For San Francisco, Cal., it was 21.54; for Galveston, Tex., 46.66; and for New Orleans, 74.98 inches.

NEW MEXICO.

The dryness of this atmosphere is proverbial. The lands are cultivated entirely by irrigation, and have been so for centuries. The tradition among the Pueblo Indians, as given by Hosti, is that, the rain falling less and less, the people emigrated to the southward long before the Spaniards arrived in the country, (the visit of Coronado was made about 1542,) being led by Montezuma, a powerful man, who was born in

Pecos and had settled with the Pueblos on the Rio San Juan. Montezuma was to return and lead the rest of the Pueblos also to the south, but he failed to come back. * * This whole tradition accords well with another held by the Aztecs, in old Mexico, when Cortez entered the country of Anahuac, namely, that their forefathers came (most probably at the end of the twelfth century) from the north. (Dr. Oscar Loew's report on "Ruins in New Mexico.") It is probable that the climate has become progressively more dry as time has elapsed, from evidences of former cultivation which would be now impossible. At Quivira, Dr. Loew says, "when Coronado visited this province it was, as he described it, very fertile; at present it resembles a desert."

At similar elevations in other countries the snow would accumulate and form glaciers upon the mountains, whence an ample river-supply of water would continue all the summer. Nothing like this occurs here, and the extremely rapid evaporation in this dry air may help to account for the difference.

II. Very soon after my arrival in New Mexico, in October, 1875, I became aware of unusual electrical disturbances around me. Severe shocks were experienced on touching garments of wool or cotton that had just been taken off, and if at night, vivid sparks of electricity and a trailing line of light would follow the fingers when passed over them. The shaking of clothing, to free it from dust, or friction with the fingers over a sheet, would have the same effect. Upon inquiry I found others also sensible of a highly electrical condition here. The telegraph was disturbed in its operations by excess of atmospheric electricity, and on inquiry of Mr. Gough, the agent of the Western Union Telegraph Line, he was happily able to confirm my impressions from a very extended experience. The subject became one of almost daily inquiry between us since July 18, 1876; and at my request he has furnished me a written statement, to which I invite special attention.

"OFFICE OF WESTERN UNION TELEGRAPH COMPANY,
"HEADQUARTERS DISTRICT OF NEW MEXICO,
"*Santa Fé, N. Mex., December* 12, 1876.

"To General T. A. MCPARLIN,
"*Surgeon, U. S. A.:*

"DEAR SIR: In reply to your question as to whether I have noticed any unusual electrical disturbances on the telegraph-lines in this region, I would respectfully state that I have noticed such disturbances, and that in character and frequency they are very remarkable, and really astonishing, and such as in a seventeen years' experience I have noticed on no other lines.

"From about the middle of April until about the middle of October, between the hours of 10 a. m. and 5 p. m., these disturbances are most frequent, and render the working of the line almost impossible.

"On my operating-table I have a galvanometer. The regular battery or artificial current on the wire deflects the needle from the north to east 60° to 65°—a steady, uniform deflection. During these electrical phenomena the needle commences to become unsteady, pointing 10, 30, 50, 70, and 90 degrees east. The flow will increase to such tremendous quantity that I have frequently opened my key an eighth of an inch, (which is equivalent to breaking the wire and separating the two ends by that distance,) when the flow of electricity would pass from point to point with a buzzing sound and an intensely brilliant flame, sometimes of a blue, sometimes of a purplish color, and as large nearly as a candle-flame. At such times I have placed tissue-paper between the points, when it would instantly commence to blaze. Thick, heavy writing-paper would be burned completely through, but would not blaze. These heavy flows will sometimes continue for hours with but little variation, at others in one instant the flow ceases entirely; the needle of the galvanometer drops down to zero; remaining so for an instant, it will fly back to 80 or 90, drop down to 10, 20, 50; the next instant the whole artificial or battery current is neutralized (so to speak) by a tremendous flow of an apparently different polarization, as the needle before deflected to the east now flows round to 70, 80, or 90 degrees to the west; the next 90 to the east, again at zero, and thus never steady for more than a few seconds at any point. I have frequently taken off all the artificial batteries entirely, and no perceptible difference could be noticed; at one moment there would be so much electricity that in trying to work the line it would fuse the platina points of the key, and in the next instant not a particle; and at no time, either with or without the artificial batteries, would the current be steady long enough to obtain intelligible signals over the wire.

"Very respectfully, your obedient servant,

JOSEPH M. GOUGH,

"*Manager Western Union Telegraph Company.*"

Referring to the Signal Service Reports last published, I found in the Monthly Reports of Weather for July, 1874, and August, 1874, electrical phenomena of special interest as connected with the summit of Pike's Peak, and for January, 1875, atmospheric electricity generally commented upon; and a special extract referring to an extraordinary electrical storm observed at Santa Fé, which I have extracted as of special interest in connection with the subject of electrical disturbances and distribution in this and other mountain regions. Facts like these should be collated and fully considered if it be determined by experience that atmospheric electricity exerts an influence upon development of health or disease.

Extracts from Report of Chief Signal-Officer for 1875.

ELECTRICAL PHENOMENA.

"The local storms previously referred to were in many instances accompanied by vivid displays of lightning. The most remarkable series

of thunder-storms occurred at the summit of Pike's Peak from the 14th to the 25th, during which the electrical effect was so intense as to interrupt telegraphic communication with that station. The observer reports that sharp peculiar sounds were emitted from all pointed objects, and that painful sensations were experienced in the hands and face.

"A brilliant display of ball-lightning was observed at Denver July 21, the ball exploding in full view and the fragments re-exploding as they reached the earth. This phenomenon was also observed at Keokuk, Iowa, on the 16th.

"Ground-currents interfered with the working of the telegraph-line at Sandy Hook on the 4th, 11th, and 16th." (Page 272, Monthly Weather Review, report for July, 1874.)

"In addition to thunder-storms spoken of under previous headings, there were strong ground-currents on the telegraph-line connecting Colorado Springs with the summit of Pike's Peak, Colo., on the evening of the 1st. Frequent lightning was observed on the same line during the month. On the 3d heavy snow accompanied a heavy thunder-storm on Pike's Peak, from which station thunder-storms are reported as having occurred almost daily. Thunder or lightning, or both, were more frequent in the Southern and Western States, especially the latter, than in other stations." (Page 276, Monthly Weather Review, report for August, 1874.)

ATMOSPHERIC ELECTRICITY.

"Thunder-storms are reported as having occurred mostly in the Southern States and during the passage of general storms, viz:

"On the 7th in Georgia and Florida; on the 21st in Georgia, North Carolina, Tennessee, Mississippi, and Texas; on the 22d in Georgia, Alabama, Mississippi, Louisiana, and Texas; on the 24th in Alabama, Mississippi, Louisiana, and North Carolina; on the 27th in Louisiana, Indian Territory, and Texas; on the 29th in Georgia and Alabama."

The following extract is made from the observer's report at Santa Fé, New Mexico:

"January 15, extraordinary electrical storm on (telegraph) line; noticed first at 12 m., and lasted until 3 p. m. The current was so strong the line could not be worked. The key was left open, and most of the line was surrounded by a ring of fire. It was during the passage of low barometer that this happened." (Page 301, Monthly Weather Review for January, 1875.) *

* By an examination of the appended papers it will be noticed that the military telegraph-line extending from Denver to Santa Fé and thence southward to Silver City was disturbed by atmospheric electricity from July 18 to December 31, 1876—deducting Sundays, when no continuous observations were made—10 times on the northern line, 14 on the southern line, and 22 on both lines out of Santa Fé; 46 days of disturbance out of 147 days' observations. No record was made of disturbances anterior to July 18, 1876.

In the year the wind traveled at a rate amounting to 67,996 miles, being southwest over one half the time and northeast or north about one-fourth the time. One hundred

The earth is a good conductor, and the "common reservoir" of electricity dry air is a good insulator; but when the air contains moisture it conducts electricity, and this, says Ganot, (page 610, Elementary Treatise on Physics, New York, 1869,) is the principal source of the loss of electricity. In the same way that metals do not become electrified by friction on account of their great conductivity, animals do not exhibit this property in a marked degree until comparatively insulated by a dry atmosphere. Animal bodies daily retaining, for any prolonged period, a greater store of electricity, or using up this electricity as a force, may be materially different from what they would be in a humid environment.

The electric tension and density of a metallic sphere is found to be uniform over its surface. On an elongated ellipsoid it accumulates at the most acute points, and the upheaved masses of mountains would appear to us favorable points for a special distribution of electric force.

It is much to be desired that observations as to the amount of ozone, of humidity, and atmospheric electricity be more generally made in the interest of those seeking for climatic relief and to furnish data for our guidance.

I have the impression that a moderate altitude should first be sought, and, as convalescence and vigor are assured, a higher and more bracing air could be borne with benefit.

In this country the statistician is at a disadvantage; there are no boards of health, no registration of diseases.

The rector of the cathedral has been kind enough to give me the statistics of deaths among the Catholic population of the parish of Santa Fé from 1869 to December 14, 1876, amounting to 1,005 deaths in eight years in a parish estimated between 7,000 and 8,000. From this I estimate the average yearly death-rate, 125, being about one death to 60 Catholic population, a mortality of 16 per 1,000 in the parish.

Of the death-rate in the Territory I have no information. Dr. Lewis Kennon, (of Fort Selden,) as quoted by Mr. Brevoort, says: "The lowest death-rate from tubercular diseases is in New Mexico."

"The censuses of 1860 and 1870 give 25 per cent. in New England, 14 in Minnesota, from 5 to 6 in different Southern States, and 3 per cent. in New Mexico." (New Mexico, by Elias Brevoort, 1874, p. 27.)

Dr. Symington informs me that, in a residence of eight years in this Territory, he has seen but two cases of phthisis among natives, and they were young persons.

In Switzerland (according to Dr. Lombard, of Geneva, Gazette des Hospitaux, of October 26, 1876; London Medical Times and Gazette,

and nine days were moist for a while from rain or snow. It is proper, however, to remark that in the rainy or wet season of the year sunshine and clear skies are noticed every day, the rain coming in showers. The whole amount of humidity was only 15.06 inches for the year; maximum velocity of wind, 38 miles per hour.

I take pleasure in acknowledging the prompt facilities extended to me by the United States signal and military telegraph services in furnishing information and data as to observations made by them.

November 11, 1876, p. 552) the mean mortality resulting from phthisis pulmonalis is 77 per 1,000 deaths, being a much lower proportion than most of the countries of Europe. Thus in Belgium this varies from 168 to 198, and in England is 124. * * * Two influences are brought into view by Dr. Lombard's investigations, viz: The deleterious effects of industrial occupations as compared to agricultural, and the benefit of high altitudes, cases of phthisis being less frequent in proportion to the height attained, so that it entirely disappears in high valleys.

The Medical Statistics United States Army—Abstract of Principal Diseases—show a total of 8 cases (3 deaths) in an average mean strength of 5,873 troops, from phthisis pulmonalis, in the six years from 1849 to 1854. For the same period, in diseases of the respiratory system, "New York, New England, and the region about the great lakes exhibit the largest ratios; and Florida, Texas, and New Mexico the smallest, being, in the ratio of cases per 1,000 of mean strength, New England, 4.8; New York harbor, 5.9; great lakes, 4.5; Atlantic coast of Florida, 2.3; Gulf coast of Florida, 6.9; Texas southern frontier, 4.00; western frontier of Texas, 3.9; New Mexico, 1.3." The conclusions of Dr. R. H. Coolidge, U. S. A., the compiler, (Medical Statistics United States Army,) are, I believe, accepted to-day: "1st. That temperature, considered by itself, does not exert that marked controlling influence upon the development or progress of phthisis which has been attributed to it. * * 2d. That the most important atmospherical condition for a consumptive is dryness. * * 3d. That next to dryness in importance is an agreeable temperature—a temperature uniform for long periods, and not disturbed by sudden or frequent changes. * * A uniformly low temperature is much to be preferred to a uniformly high temperature. The former exerts a tonic and stimulating effect upon the general system, while the latter produces general debility and nervous exhaustion. The worst possible climate for a consumptive is one with a long-continued high temperature and a high dew-point."

Confirmatory of all this, and the fact that "New Mexico is by far the most favorable residence in the United States for those predisposed to or affected with phthisis," may be consulted the testimony and experience of several medical officers of the United States Army. (Quoted in Hammond's Hygiene, p. 280.)

An examination of the sickness and mortality tables of the troops serving in New Mexico from 1861 to 1865, published in the Medical and Surgical History of the War of the Rebellion, Part I, Washington, 1870, pp. 138, 280, 436, and 588, Order V, Diseases of the Respiratory Organs, shows the following cases:

Diseases.	1861–'62.	1862–'63.	1863–'64.	1864–'65.	Total cases.	Deaths.
Asthma		4	16	8	28	
Acute bronchitis	24	156	139	158	477	
Chronic bronchitis	3	5	13	30	51	1
Catarrh	353				353	
Hemorrhage from nose	1	2	4		7	1
Hemorrhage from lungs	3	4	6	6	19	
Dropsy of chest			1		1	1
Inflammation of larynx	5	12	31	58	106	4
Inflammation of the pleura	23	28	61	38	150	3
Inflammation of the lungs	39	78	63	106	283	37
Other diseases of respiratory organs	9	109	103	39	260	2
Total of respiratory organs	461	398	437	443	1,739	49
Total diseases and injuries all kinds	6,956	9,144	8,066	7,245	31,411	
Total deaths all kinds	72	52	74	90		288
Mean strength	3,460	3,762	4,224	3,866		
Aggregate					15,312	
CLASS II.—ORDER II. *Tubercular diseases.*						
Consumption	10	13	8	10	41	8

List of cases of consumption and of diseases of the respiratory organs treated during the ten years from January 1, 1867, to December 31, 1876, at Santa Fé, N. Mex.

Diseases.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Total cases.	Deaths.
Asthma	1								1		2	
Catarrh	4			1	4	15	3	10	34	35	102	
Acute bronchitis	3	9							1		13	
Chronic bronchitis						1					1	
Inflammation of larynx			1								1	
Inflammation of lungs						1	1		1	2	5	2
Inflammation of pleura						1				1	2	
Total respiratory organs	8	9	1	1	4	18	4	10	37	38	126	2
Consumption			1		1						2	2
Mean strength	88	70	80	71	76	82	75	90	95	94		
Aggregate											821	

Many persons do well at home in summer who need in winter a milder climate.

Europeans are wont to seek Naples, Malaga, Egypt, Algiers, Rome, Florence, Mentone, or the West Indies. Recently the west coast of Ireland, made warm by the influence of the Gulf Stream, has been recommended. For patients threatened with phthisis, Mentone, Malaga, and Algiers are preferable. If they go to Jamaica, they should arrive in December and go up at once to the hills. Such as are affected with irritable bronchitis, asthma, and pleuritic tendencies, are recommended to Madeira, and in the spring to Pau. (London Med. Times and Gazette, November 4, 1876, p. 519.)

When the railroad shall have made this region (of New Mexico) of easy access, the invalid may find a genial and proper climate. For the weakest invalids the Mesilla Valley should be first resorted to, and

thence the transit can be made to a northern and more invigorating air. The summer in Mesilla is said to be quite hot.

Proceeding from Santa Fé, between Taos and Fort Garland, the military wagon-road—conducted by Lieutenant Ruffner—winds in the cañon of the Rio Grande and near its margin for miles. The river is narrow and rapid, hemmed in by peaks and precipices, and rushes a foaming flood over rocks and bowlders.

The Denver and Rio Grande Railroad, which will be extended to Garland by May 1, 1877, will probably come down this cañon and open out some magnificent scenery to the tourist. Arriving at Fort Garland, situated in the San Luis Park, (8,000 feet above sea-level,) we have a near view of the Sierra Blanca, one of the highest of the Rocky Mountains—14,404 feet—easier of ascent than Mont Blanc, (15,784 feet,) the Jung Frau, (13,671 feet,) or the Matterhorn, (14,370 feet.) A daily line of stages passes Garland toward the San Juan mines, reaching the Rio Grande River in 26 miles, in 60 miles La Loma and Del Norte, and in about 100 miles the summit of the main divide, "among a mass of snow-peaks, in groups connected by crests more or less high, from which the waters flow radially, and is probably the highest portion of the Rocky Mountains. This region, like that of the Yellowstone Lake, seems to be one of the domes of the continent, as is shown by the fact that the same rivers which eventually flow west flow at first east and south, like Grand River and Lake Fork." (Reconnaissance in the Ute country by First Lieut. E. H. Ruffner, United States Engineers, Washington, 1874, p. 31.) Among those mountains whose heights have been determined, we have Summit, 13,356 feet; Bristol Head, 11,814 feet; King Solomon, 13,073 feet; Engineer Mountain, 13,270 feet. The highest of all is Mount Chauvenet, altitude unknown to me. King Solomon, in the Sierra La Plata, and Mount Galena (12,978 feet) are in the rich silver and gold mining region, now rapidly filling up by immigration.

From Engineer Mountain "masses of snow-peaks rising a thousand and two thousand feet above timber are seen, with sky-lines marvelously bold and wild. The peaks (says Maj. H. G. Prout) are seen at distances of 10 to 30 miles around. I doubt if any other mountain region in the world displays so extensive a mass of increasing variety of form so wholly grand." (Page 24, *ibid.*)

The great overland California Railway passes over no country equal to this, as it purposely and economically was located at a lower level. Here, about latitude 37° 45′ and longitude 107° 28′, the Great Sierra Madre rises to its greatest height, and thence flow the fountains of the Rio Grande del Norte.

Appendix No. 1.

Santa Fé, *December* 14, 1876.

Dr. McParlin:

Dear Sir: According to your request, I have the honor to send the statistics of deaths occurred among the Catholic population of the par ish of Santa Fé since I have been the rector of the said parish.

The parish of Santa Fé, as it is now established, comprises, besides the city, the towns of Agua Fria, Cienega, Tesuque, and Rio Tesuque; it is to say, a population of seven or eight thousand inhabitants.

Here are now the statistics of deaths:

Years.	Deaths.	Years.	Deaths.
1869	104	1873	120
1870	94	1874	146
1871	145	1875	102
1872	183	1876, up to this date	131

As to the principal causes of these deaths I ought to confess my ignorance in the matter. I am not a physician.

Influenza and whooping-cough are sometimes fatal and very mortiferous, especially among children. In last January and February, as you must be aware, we had many fatal cases of pleurisy. I buried 32 corpses, almost all of grown persons.

It would be an error to believe that there is no case of consumption among the natives of this country. On the contrary, asthma, heart and lung diseases are very common among them. I have actually some patients who suffer of such affections.

I think the principal cause must be attributed to the sharpness of the air and scarcity of good clothes.

I am, very respectfully, my dear doctor, your most obedient servant,

J. A. BRUCHARD,

Parish Priest of the Cathedral.

A true copy:

T. A. McParlin, M. D.

APPENDIX No. 2.

Monthly means for 1876, Santa Fé, N. Mex.

Date.	Barometer.				Mean humidity.	Thermometer.				Wind.			Amount of rain or snow.		Number of auroras.
	Mean.	Range.				Mean.	Range.			Prevailing direction.	Maximum velocity.	Total miles traveled.	Amount in inches.	Number of days on which fell.	
		Highest.	Lowest.	Difference.			Maximum.	Minimum.	Difference.						
1876.															
January	29.782	30.061	29.377	.684	46.8	29.0	55	5	50	N. E.	28	4,879	.60	7	0
February	29.785	30.091	29.351	.740	38.7	32.8	57	13	44	N. W.	32	5,796	.40	7	0
March	29.636	29.992	29.705	.787	45.1	36.5	60	5	55	S. W.	33	7,664	.64	8	0
April	29.766	30.030	29.369	.661	42.1	50.2	78	13	65	S. W.	32	6,123	.46	3	0
May	29.775	30.032	29.387	.645	40.9	55.9	78	28	50	S. W.	35	6,818	.83	8	0
June	29.823	30.017	29.603	.414	46.7	66.0	88	40	48	S. W.	36	6,570	1.62	11	0
July	29.910	30.049	29.691	.358	64.6	69.2	87	50	37	E.	24	5,281	5.43	18	0
August	29.894	30.097	29.689	.408	67.9	65.2	89	45	44	S. W.	36	4,909	2.13	18	0
September	29.895	30.057	29.718	.339	55.7	60.2	82	38	44	S. W.	31	4,957	.85	9	0
October	29.818	30.026	29.492	.534	49.3	48.6	78	27	51	W.	38	5,471	.75	9	0
November	29.815	30.077	29.479	.598	55.5	35.7	64	10	54	N.	28	5,075	.97	6	0
December	29.755	30.055	29.033	1.022	45.9	28.5	52	— 1	53	N.	24	4,553	.38	5	0
Annual means	29.796	30.049	29.450	.599	49.9	48.1	72.3	22.5	49.6	S. W.		67,996	15.06	109	0

Date.	Time.	Barometer.	Thermometer.	Humidity.	Direction of wind.	Velocity of wind.	Amount of clouds.	Rain-fall.	Weather.	Mean daily— Barometer.	Mean daily— Thermometer.	Mean daily— Humidity.	Thermometer. Maximum.	Thermometer. Minimum.	Remarks.
1876.															
July 18	7 a. m.	30.01	60	82	S.W.	2		0	Cloudy.....	30.002	64.5	72.7	73	55	
18	2 p. m.	29.97	72	58	S. E.	12		0	Fair						
18	9 p. m.	30.01	63	78	S. E.	12		.10	Fair						
19	7 a. m.	29.99	65	73	E.	1	3-4	0	Fair	29.97	69.2	72.0	76	52	After 3 p. m. the telegraph failed to work until midnight, (of 18–19.) Rain and thunder storm in vicinity.
19	2 p. m.	29.95	74	59	S.	9	2-4	0	Fair						
19	9 p. m.	29.96	69	84	W.	12	4-4	.18	Light rain ..						
20	7 a. m.	29.99	64	82	N.	5	1-4	.03	Clear	30.00	62.7	78.0	77	56	Line failed to work all afternoon. Did not work well all day, (19–20.)
20	2 p. m.	29.97	67	74	N.	11	4-4	.09	Cloudy						
20	9 p. m.	30.01	60	88	S.	3	2-4	0	Fair						
21	7 a. m.	30.04	61	82	E.	1	3-4	0	Fair	30.01	63.2	78.7	76	56	About 3 hours in the afternoon the line would not work on account of lightning, (storm.)
21	2 p. m.	29.99	74	72	S. W.	5	3-4	0	Fair						
21	9 p. m.	30.01	59	82	E.	4	3-4	.21	Fair						
22	7 a. m.	30.05	66	78	E.	4	2-4	0	Fair	30.03	66.2	67.0	77	56	Southern line was interrupted by a storm nearly all the afternoon.
22	2 p. m.	29.99	75	59	S.	10	2-4	0	Fair						
22	9 p. m.	30.05	63	78	E.	6	0	0	Clear						
23	7 a. m.	30.04	67	74	E.	2	1-4	0	Fair	29.967	69.0	70.3	78	56	No observation of effect of electricity.
23	2 p. m.	29.97	77	60	S. W.	7	2-4	0	Fair						
23	9 p. m.	29.93	66	78	S. E.	3	0	0	Clear						
24	7 a. m.	29.93	68	65	N.	1	2-4	0	Fair	29.90	72.0	65.7	84	56	The telegraph worked badly on the 24th. The southern line worked between 2 p. m. and 7 p. m. The northern line had plenty of electricity all the afternoon. At night a thunder-storm with rain 2 or 3 hours.
24	2 p. m.	29.88	82	62	S. W.	7	3-4	0	Fair						
24	9 p. m.	29.90	69	70	W.	18	4-4		Light rain ..						
25	7 a. m	29.94	63	83	S.	1	1-4	.62	Clear	29.906	68.0	72.5	78	58	About 4 to 6 p. m. the line (south and north) worked badly.
25	2 a. m.	29.89	77	69	S. W.	2	2-4	0	Fair						
25	9 p. m.	29.89	66	68	N. E.	12	3-4	0	Fair						
26	7 a. m.	29.91	65	78	N.	8	0	0	Clear	29.916	71.0	64.3	82	58	The line worked all day; at times not with ease, but still successfully.
26	2 p. m.	29.90	79	54	S. W.	14	3-4	0	Fair						
26	9 p. m.	29.92	70	61	E.	12	0	0	Clear						
27	7 a. m.	29.99	71	62	N. E.	1	0	0	Clear	29.966	70.2	67.3	83	59	From 2 p. m. to 6 p. m. the line worked, but with great difficulty.
27	2 p. m.	29.97	68	79	N. E.	20	3-4	.01	Fair						
27	9 p. m.	29.95	70	61	S. E.	4	0	0	Clear						
28	7 a. m.	29.98	72	67	E.	4	1-4	0	Clear	29.943	74.5	64.0	85	60	Very little trouble working the line; perhaps for 2 hours in the afternoon there was a little difficulty.
28	2 p. m.	29.93	80	62	N. E.	1	3-4	0	Fair						
28	9 p. m.	29.93	73	63	S. E.	6	3-4		Fair						
29	7 a. m.	30.00	73	63	E.	1	0	0	Clear	29.96	76.0	60.0	87	60	Line worked all day; a very little disturbance, but not material.
29	2 p. m.	29.94	85	54	S. W.	1	2-4	0	Fair						
29	9 p. m.	29.95	73	63	S. E.	2	0	0	Clear						

METEOROLOGY OF NEW MEXICO—Continued.

Date.	Time.	Barometer.	Thermometer.	Humidity.	Direction of wind.	Velocity of wind.	Amount of clouds.	Rain-fall.	Weather.	Mean daily— Barometer.	Mean daily— Thermometer.	Mean daily— Humidity.	Thermometer. Maximum.	Thermometer. Minimum.	Remarks.
1876.															
July 30	7 a. m.	30.00	74	63	E.	1	0	0	Clear	29.93	75.5	58.3	86	63	Sunday. No observation made as to working of line.
30	2 p. m.	29.92	84	50	S. W.	6	2-4	0	Fair						
30	9 p. m.	29.91	72	62	E.	6	0	0	Clear						
31	7 a. m.	29.94	73	63	E.	1	1-4	0	Fair						
31	2 p. m.	29.91	85	57	S. W.	10	2-4	0	Fair	29.91	71.0	64.3	87	61	Line worked well yesterday; a little disturbance on the southern line in the afternoon, but not material.
31	9 p. m.	29.90	69	65	S.	2	2-4	0	Fair						
Aug. 1	7 a. m.	29.97	69	70	N.	4	2-4	0	Fair						
1	2 p. m.	29.93	86	65	S. W.	3	2-4	0	Fair	29.94	73.7	65.0	89	63	The northern line worked badly all the afternoon. The southern line worked well, except when there was a break somewhere about 5 or 6 o'clock p. m.
1	9 p. m.	29.93	70	70	E.	8	2-4	0	Fair						
2	7 a. m.	29.97	67	69	E.	1	2-4	0	Fair						
2	2 p. m.	29.90	79	73	N.	4	2-4	0	Fair	29.903	70.5	73.7	88	61	A great deal of trouble with the line all afternoon. On the northern line, trouble in the forenoon. Storm near Trinidad yesterday.
2	9 p. m.	29.87	68	79	N.	4	1-4	.11	Fair						
3	7 a. m	29.91	69	70	Calm.	0	0	0	Clear						
3	2 p. m.	29.88	77	77	N. E.	4	4-4	0	Cloudy	29.90	70.0	77.0	84	56	Considerable trouble in working the line all the afternoon. More on the southern, but still enough on both.
3	9 p. m.	29.90	67	84	N. E.	2	4-4	0	Cloudy						
4	7 a. m.	29.86	68	69	E.	1	2-4	0	Fair						
4	2 p. m.	29.81	76	64	N.	3	4-4		Cloudy	29.81	68.0	68.3	85	54	There was trouble in working all the afternoon, more or less.
4	9 p. m	29.80	64	72	N.	3	3-4	.01	Fair						
5															No trouble.
6															No observation. (Sunday.)
7	7 a. m.	30.06	69	75	S. E.	3	3-4	0	Fair	30.03	63.7	86.0	81	56	The southern line worked badly, but worked as far down as Selden. The northern line worked badly, the worst for some time.
7	2 p. m	30.03	64	89	N. W.	12	4-4	.08	Light rain						
7	9 p. m	30.02	61	94	S. E.	3	4-4	.02	Light rain						
8															Very little trouble.
9	7 a. m.	29.77	67	74	N.	2	2-4	0	Fair	29.71	64.0	82.0	80	54	A good deal of trouble all the afternoon on northern line.
9	2 p. m.	29.71	67	84	N. W.	16	4-4	.02	Light rain						
9	9 p. m	29.69	61	88	N.	6	0	.05	Clear						
10	7 a. m.	29.80	64	78	N. E.	5	0	0	Clear	29.81	66.7	73.0	81	52	Southern line did not work at all; the line was probably grounded somewhere. Northern line worked well all day.
10	2 p. m	29.81	79	58	S.	8	1-4	0	Fair						
10	9 p. m.	29.83	62	83	S. E.	16	0	0	Clear						
11															Very little trouble.
12															No remarks.
13															No observations. (Sunday.)
14															No remarks.
15	7 a. m.	29.90	61	94	Calm.	0	2-4	0	Fair	29.88	65.7	83.7	81	55	Some, but very little, trouble experienced in working the line.
15	2 p. m.	29.86	70	79	S. W.	4	4-4	.03	Cloudy						
15	9 p. m	29.88	66	78	E.	6	2-4	.02	Fair						

16	7 a. m.	29.93	66	78	E.	3	2-4	0	Fair	29.93	67.0	72.3	81	50	A large amount of electricity on the line from 11 a. m. until 7 p. m. on both lines; much difficulty in working experienced.	
16	2 p. m.	29.80	76	56	W.	5	4-4	0	Cloudy							
16	9 p. m.	29.94	63	83	N. E.	6	4-4		Light rain							
17															No remarks.	
18	7 a. m.	29.93	68	69	S.	3	0	0	Clear	29.91	67.7	70.0	85	56	Southern line worked until 11 a. m., then very badly all the rest of the day. Northern line, pretty much the same.	
18	2 p. m.	29.84	81	59	S. W.	11	2-4	0	Fair							
18	9 p. m.	29.93	61	82	S. E.	16	4-4		Light rain							
19	7 a. m.	29.90	59	76	N.	6	4-4	.19	Cloudy	29.88	62.7	73.3	73	54	Too much lightning and storm all day, and great difficulty experienced.	
19	2 p. m	29.87	72	62	S. W.	13	3-4	.44	Fair							
19	9 p. m.	29.87	60	82	S. E.	5	4-4	.43	Clear							
20															No observation. (Sunday.)	
21	7 a. m.	29.85	64	67	E.	5	3-4	0	Fair	29.80	65.7	62.7	78	52	Great electrical disturbance in the afternoon and until after midnight.	
21	2 p. m.	29.81	73	54	S. W.	8	3-4	0	Fair							
21	9 p. m.	29.78	63	67	S.	9	2-4		Fair							
22															Very little trouble.	
23															No trouble.	
24															Do.	
25	7 a. m.	30.09	59	54	N. E.	8	3-4	0	Fair	30.04	61.5	55.0	70	45	Storm near Fort Craig interfered with southern line in the afternoon; northern line worked well.	
25	2 p. m	30.03	69	47	S.	12	3-4	0	Fair							
25	9 p. m.	30.02	59	64	S. E.	15	2-4	0	Fair							
26	7 a. m.	29.98	62	66	S. E.	1	3-4	0	Fair	29.95	57.2	78.3	66	54	The line was grounded between Craig and Belen; after it was set up the lightning prevented working; northern did not work in the afternoon.	
26	2 p. m.	29.95	61	88	S. E.	10	3-4	.05	Fair							
26	9 p. m.	29.93	58	81	S. E.	4	4-4	.10	Cloudy							
27															No trouble.	
28	7 a. m	29.90	58	67	E.	4	2-4	0	Fair	29.85	63.0	57.0	78	45	Considerable lightning, especially in the afternoon, which interfered with working from 2 p. m. until night.	
28	2 p. m.	29.83	74	39	N. W.	4	3-4	0	Fair							
28	9 p. m.	29.84	60	65	S. E.	8	4-4	.05	Cloudy							
29															No trouble.	
30															Do.	
31															Do.	
Sept. 1	7 a. m.	30.03	59	70	E.	1	4-4	0	Light rain				81	55	Considerable trouble on northern line all day; great deal of electrical disturbance; southern line would not work at all after 2 p. m.	
1	2 p. m.	29.99	71	44	E.	12	2-4		Fair							
1	9 p. m.	30.01	61	56	E.	18	3-4		Fair							
2	7 a. m.	30.06	60	82	S. E.	1	3-4	0	Fair	29.96	65.0	64.7	75	55	Southern line worked badly in afternoon; considerable lightning, south of Fort Craig principally.	
2	2 p. m	29.96	74	55	W.	6	3-4	0	Fair							
2	9 p. m.	29.93	63	55	E.	11	3-4	0	Fair							
3	7 a. m.	29.94	58	81	Calm.	0	3-4	0	Fair	29.91	63.0	67.3	82	52	Considerable electrical disturbance; not much continuous work done, it being Sunday.	
3	2 p. m.	29.84	80	40	S. W.	6	3-4	0	Fair							
3	9 p. m.	29.93	57	81	N. E.	16	4-4	.07	Cloudy							
4	7 a. m.	29.90	64	67	N. E.	3	0	0	Clear	29.85	67.0	58.3	81	51	Northern line down; southern line troubled from 1 to 4 p. m. with lightning; other times line worked reasonably well.	
4	2 p. m.	29.84	78	46	S. W.	10	2-4	0	Fair							
4	9 p. m.	29.85	63	62	S.	1	2-4	0	Fair							
5	7 a. m.	29.86	63	72	Calm.	0	2-4	0	Fair	29.83	62.7	63.7	82	57	Southern line troubled all afternoon with lightning; northern line worked well.	
5	2 p. m.	29.82	70	43	N.	15	3-4	0	Fair							
5	9 p. m.	29.83	59	76	S. E.	2	2-4	0	Fair							
6															No trouble.	
7	7 a. m.	29.81	60	49	N.	11	3-4	0	Fair	29.780	64.2	47.0	77	53	Northern line worked well all day; southern line had some lightning, (storm near Mesilla,) which caused some trouble in the afternoon, but the line was worked notwithstanding.	
7	2 p. m.	29.77	73	38	S. W.	6	2-4	0	Fair							
7	9 p. m	29.77	62	61	S. E.	8	2-4	0	Fair							
8															No trouble.	
9															Do.	

METEOROLOGY OF NEW MEXICO—Continued.

Date.	Time.	Barometer.	Thermometer.	Humidity.	Direction of wind.	Velocity of wind.	Amount of clouds.	Rain-fall.	Weather.	Mean daily— Barometer.	Mean daily— Thermometer.	Mean daily— Humidity.	Thermometer. Maximum.	Thermometer. Minimum.	Remarks.
1876.															
Sept. 10															No trouble.
11															Do.
12															Do.
13	7 a. m.	29.99	55	50	N. W.	3	0	0	Clear	29.942	62.7	38.3	72	43	No trouble on northern line; on southern, late at night, a heavy storm south produced electrical disturbance.
13	2 p. m.	29.95	70	32	S.	12	2-4	0	Fair						
13	9 p. m.	29.96	63	33	E.	16	2-4	0	Fair						
14	7 a. m.	30.00	60	49	N. W.	2	2-4	0	Fair	29.99	59.1	54.3	68	50	Some lightning on northern line; considerable disturbance from lightning all the afternoon on southern line; storm principally south of Craig, but disturbance general, even north of Craig; rain at Silver City after 6 p. m.
14	2 p. m.	29.96	63	51	S.	14	2-4	0	Fair						
14	9 p. m.	30.00	57	63	E.	15	2-4	0	Fair						
15	7 a. m.	29.94	56	71	Calm.	0	2-4	0	Fair	29.872	59.2	64.0	77	49	A good deal of trouble during day on northern line on account of lightning; on southern line, from 4.30 to 7 30 p. m., there was also trouble.
15	2 p. m.	29.84	73	42	S. W.	9	3-4	0	Fair						
15	9 p. m.	29.85	54	79	Calm.	0	2-4	.01	Fair						
16	7 a. m.	29.81	53	79	0	0	4-4	0	Cloudy.....	29.773	56.0	65.7	69	47	On southern line, between 2 and 4.30 p. m., there was disturbance from lightning south of Fort Selden; some trouble on northern line also in afternoon.
16	2 p. m.	29.76	67	46	S. W.	20	3-4	0	Fair						
16	9 p. m.	29.76	52	72	W.	1	1-4	0	Clear						
17	7 a. m.	29.78	48	85	Calm.	0	3-4	0	Fair	29.746	58.2	61.7	73	47	Northern line had trouble between 5 and 6 p. m.; heavy storm north of Colorado Springs.
17	2 p. m	29.75	69	47	S.	8	2-4	0	Fair						
17	9 p. m.	29.73	58	53	N. E.	10	2-4	0	Fair						
18	7 a. m.	29.74	46	100	N. W.	3	4-4	.08	Cloudy	29.735	48.2	82.7	62	43	A great deal of trouble from lightning on northern line, particularly in the afternoon; southern line, no trouble.
18	2 p. m.	29.73	51	78	S. E.	8	3-4	.13	Fair						
18	9 p. m.	29.73	58	70	N.	5	2-4		Fair						
19															No trouble.
20															Do.
21															Do.
22															Do.
23															Do.
24															Do.
25															Do.
26															Do.
27	7 a. m.	29.99	55	74	S. E.	5	4-4	0	Cloudy	29.964	54.2	69.7	60	53	Southern line, some trouble caused by storm at Selden and south from 10 a. m. until 6.30 p. m.; no trouble from lightning on northern line.
27	2 p. m.	29.96	56	62	E.	13	4-4	0	Cloudy						
27	9 p. m.	29.96	53	73	E.	5	4-4	0	Cloudy						
28															No trouble.
29	7 a. m.	30.03	50	78	E.	4	0	0	Clear	29.95	56.7	73.0	67	41	Northern line, no trouble during day; some trouble at night, due to a heavy storm northward. No trouble on southern line.
29	2 p. m.	29.93	65	63	W.	6	2-4	0	Fair						
29	9 p. m.	29.92	56	78	S.	3	3-4	0	Fair						

	30	7 a. m.	29.96	42	79	N. E.	2	2–4	0	Fair	29.946	48.2	71.0	63	38	Southern line, slightly disturbed by lightning from 7 to 8 p. m. Northern line, no trouble.
	30	2 p. m.	29.90	61	58	S.	6	2–4	0	Fair						
	30	9 p. m.	29.96	45	76	S. E.	5	4–4	0	Cloudy						
Oct.	1															No trouble.
	2	7 a. m.	29.92	46	85	N. E.	2	1–4	0	Clear	29.872	53.7	53.3	66	39	Northern line, no trouble. Southern line, slight electrical disturbance by storm at Bayard and Silver City.
	2	2 p. m.	29.86	65	22	N. W.	15	0	0	Clear						
	2	9 p. m.	29.86	52	53	N. E.	4	0	0	Clear						
	3															No trouble.
	4															Do.
	5															Do.
	6															Do.
	7															Do.
	8															Do.
	9	7 a. m.	29.95	48	77	S. E.	2	sm'ke	0	Clear	29.88	57.0	51.7	73	42	Northern line, great electrical disturbance; at times the atmospheric current overcame the artificial current and deflected the needle from north to east about 30° or 40°. Southern line, slight electrical disturbance between 2.30 and 7.30 p. m. Storm near Mesilla and Fort Selden.
	9	2 p. m.	29.85	70	28	N. W.	8	3–4	0	Fair						
	9	9 p. m.	29.88	55	50	S. E.	6	0	0	Clear						
	10	7 a. m.	29.89	51	59	E.	1	0	0	Clear	29.892	55.0	49.0	74	43	Northern line, slight electrical disturbance from local storm about 3 p. m. Southern line, slight electrical disturbance during the afternoon.
	10	2 p. m.	29.86	67	29	S. E.	20	3–4	0	Fair						
	10	9 p. m.	29.91	51	59	N. E.	3	2–4	.02	Fair						
	11	7 a. m.	29.93	53	66	S. E.	8	0	0	Clear	29.901	56.0	48.7	68	43	Northern line, good deal of trouble (electrical disturbance) during the afternoon from 3 p. m. Southern, line no trouble.
	11	2 p. m.	29.87	65	26	S.	14	3–4	0	Fair						
	11	9 p. m.	29.90	53	54	S. E.	10	1–4	0	Fair						
	12															No trouble.
	13															Do.
	14	7 a. m.	29.90	46	76	E.	2	3–4	0	Fair	29.938	48.5	61.7	65	41	Southern line, slight disturbance from 2 p. m. till 8 p. m., (electrical.) Northern line, no trouble.
	14	2 p. m.	29.89	58	41	E.	18	2–4	0	Fair						
	14	9 p. m.	29.98	45	68	N.	6	1–4	0	Clear						
	15															No trouble.
	16															Do.
	17															Do.
	18															Do.
	19															Do.
	20															Do.
	21															Do.
	22															Do.
	23															Do.
	24															Do.
	25															Do.
	26															Do.
	27															Do.
	28															Do.
	29															Do.
	30															Do.
	31	7 a. m.	29.76	40	56	S. E.	8	4–4	0	Threatening	29.690	38.2	65.0	53	32	Northern line, had a good deal of trouble from 2 p. m. to 4 p. m., due to electricity; southern line, couldn't work from 1 p. m. to 4.30 p. m., on account of electrical disturbances, seemingly the entire length of the line; began raining at 2.15 p. m., and snowing at 2.45 p. m.; continued all day and night at intervals.
	31	2 p. m.	29.65	49	50	S. E.	11	4–4		Cloudy						
	31	9 p. m.	29.68	32	89	N.	4	4–4	.52	Cloudy						
Nov.	1															No trouble.

METEOROLOGY OF NEW MEXICO—Continued.

Date.	Time.	Barometer.	Thermometer.	Humidity.	Direction of wind.	Velocity of wind.	Amount of clouds.	Rain-fall.	Weather.	Mean daily— Barometer.	Mean daily— Thermometer.	Mean daily— Humidity.	Thermometer. Maximum.	Thermometer. Minimum.	Remarks.
1876.															
Nov. 2															No trouble.
3															Do.
4															Do.
5															Do.
6															Do.
7															Do.
8															Do.
9															Do.
10															Do.
11															Do.
12	7 a. m	29.61	39	91	E.	6	4-4	.20	Threatening	29.584	38.7	81.3	45	38	Northern line, no trouble; southern line, very slight electrical disturbance at 2 p. m.
12	2 p. m	29.55	42	74	S. E.	11	4-4	.07	Light rain						
12	9 p. m	29.58	37	80	N. E.	12	4-4	.16	Light rain						
13															No trouble.
14															Do.
15															Do.
16															Do.
17															Do.
18															Do.
19															Do.
20															Do.
21															Do.
22	7 a. m	29.73	29	89	N. E.	2	4-4	.02	Light snow	29.818	26.0	72.0			Northern line, no trouble; southern line, slight electrica disturbance, caused by storm at Mesilla and vicinity.
22	2 p. m	29.75	31	60	N. W.	6	4-4	.03	Cloudy						
22	9 p. m	29.90	22	72	W.	2	3-4	0	Fair						
23															No trouble.
24															Do.
25															Do.
26	7 a. m	29.74	38	46	N.	27	1-4	0	Clear	29.686	41.5	39.3	52	35	Northern line, some disturbance from electrical causes and during high wind; southern line, no disturbance.
26	2 p. m	29.67	50	25	N.	18	2-4	0	Fair						
26	9 p. m	29.67	39	47	N.	7	2-4	0	Fair						
27															No trouble.
28															Do.
29															Do.
30															Do.
Dec. 1–31*															Do.

* Inclusive.

ON THE CHANGE OF THE MEXICAN AXOLOTL TO AN AMBLYSTOMA.

By Dr. August Weismann, *Professor at Freiburg, Breisgau.*
[Translated by Henry M. Douglass, Champaign, Ill.]

Since Duméril first announced the change of a number of Axolotls into the so-called Amblystoma form, this Mexican fish-salamander has been bred in aquariums at many European places, principally with a view to determine the conditions under which that change occurs, and then from that to draw further conclusions upon the real causes of this exceptional and therefore so mysterious metamorphosis.

The creatures were easily propagated everywhere, and that in great numbers. Yet not only did the cases in which the transformation occurred remain exceedingly rare, but no one succeeded in answering the first and most important question, whether this was called forth by *external* circumstances or was dependent upon purely intrinsic causes. Much less were any *definite* external influences found through whose presence one could bring on the metamorphosis with certainty.

But until this point is decided, all attempts at theoretical interpretation and use of the phenomenon must remain without any firm foundation.

To me this history of the Axolotl's transformation always seemed to be of quite a particular interest. I believed, indeed, that possibly this *one* special case might be sufficient to determine the correctness of the fundamental principles, according to which the origin of species is represented in the two hostile camps of *development* and *heterogeneous* or *distinct* creation. So I resolved to set about experiments with the Axolotl myself, in the hope that perhaps it would be my good fortune to throw some light upon this subject.

In the year 1872, Herr von Kölliker had the kindness to present to me five of the Axolotls he had bred in Würzburg. In the following year these produced an abundant brood. With them I tried to settle the question, whether it was not possible to force all the larvæ to the change, or at least the greater part, if they were brought into circumstances which rendered the use of the gills difficult, that of the lungs easy. This, in other words, would be to compel them from a certain age to live half on the land. It will be seen further on, what theoretical grounds led me to this idea.

Meanwhile I reached no results that year. The most of the larvæ died before the time for such experiments seemed to have come. The

few survivors did not make the change, but lived until the early part of the next year, only to die one after another.

Evidently I had given them too little care and attention, being prevented by a somewhat lengthened absence from Freiburg, as well as by other labors.

I reached the conviction at that time that without the greatest carefulness and attention in the rearing no result can be obtained. This conviction further experience only confirmed. One must just concentrate all his interest upon this one aim, and must not begrudge having to devote considerable time every day for months to this work. That I could not carry this on myself, without giving up other work for it, seemed clear to me, and so I hailed it with joy when the opportunity offered of seeing the experiments made by another person.

Miss von Chauvin, a lady well known to several correspondents in this department by her beautiful observations on the Phryganidæ (alas, not yet published), proposed the following year to take a number of the larvæ just out of the egg, rear them, and make the attempt to bring them, in a certain measure, by force into the Amblystoma condition. It will be perceived by the following records of the lady herself how completely this attempt succeeded, and no less will it be seen that this success was possible only with such carefulness in the treatment and delicacy in the observation as were here employed.

EXPERIMENTS.

"I began the experiments June 12, 1874, with five larvæ about eight days old, all that remained alive of the twelve delivered to me. On account of the extraordinary tenderness of these larvæ, the quality and temperature of the water, the kind and quantity of the food supplied, especially in the earliest period, exert a great influence upon them, so that one can hardly be cautious enough in their management.

"The little creatures were kept in a glass globe of about 30 centimetres in diameter; the temperature of the water was regulated, and as nourishment Daphnida were furnished at first, afterward larger aquatic animals in greater quantity. In this way the five larvæ throve exceedingly well. By the end of June the strongest larvæ showed the beginning of the fore legs, and the 9th of July the hind legs made their appearance. At the end of November I noticed that one Axolotl—for brevity I distinguish it with I., and shall note the others with the successive Roman numerals—kept constantly on the surface of the water, which brought me to the supposition that the right time had come to prepare for the change to a land salamander.

"For this purpose, on December 1, 1874, I. was put into a considerably larger glass vessel with a flat bottom, which was so placed and filled with water that only in one spot could he dive quite under water, while everywhere else in his repeated creepings about the bottom of the vessel he came more or less in contact with the air. On the following days the

water was gradually diminished, and during this time the first changes in the animal appeared: *The gills began to shrivel.* At the same time the creature showed a striving to reach the shallow places. The 4th of December it betook itself wholly to the land and crept away into the damp moss which I had placed on a bed of sand in the highest part of the bottom. This was followed by the first molt. Within the four days from December 1 to 4 a striking change took place in the exterior of I.; the gill-tufts shriveled almost entirely together, the crest on the back vanished completely, and the hitherto broad tail assumed a rounded form similar to a land salamander's tail. The grayish-brown color of the body gradually changed to blackish; here and there white spots came out, faintly marked at first, and growing more distinct.

"When, on the 4th of December, the Axolotl crept out of the water, the clefts of the gills were still open, but they gradually closed, and in about eight days they were no longer to be seen and were grown over with a skin.

"Of the other larvæ, at the end of November (that, is at the same time when I. came to the surface of the water), three more were just as strongly developed as I.—an indication that for them also the right time had come for the hastening of the process. They were therefore subjected to the same treatment. II. changed in fact at the same time as I., and, precisely like it, had perfect gill-tufts when it was placed in the shoal water, and *after four days* had almost completely divested itself of these. He went upon the land; and then followed, in the *course of about ten days, the growing over of the gill-clefts and the complete assumption of the salamander's form.* During this last time the animal took food, but only when he was urged.

"With III. and IV. the change went on more slowly. They did not so frequently seek for the drier places, and generally did not expose themselves so long to the air, so that the greater part of January passed before they took wholly to the land. Yet the drying of the gill-tufts required no longer time than I. and II. The first molt also followed as soon as they crept upon the land.

"V. showed much more remarkable deviations in the transformation than III. and IV. As this individual from the beginning appeared much more feeble than the others, and also staid behind remarkably in its growth, this was by no means surprising. It required fourteen days instead of four to carry the change so far that it could leave the water. It was of quite peculiar interest to watch the condition of this individual during this time. As may be inferred from its delicate nature, it was more sensitive than the others to all outward influences. If it was exposed to the air too long it took on a lighter color. Besides it gave off a peculiar odor, similar to what salamanders diffuse when they are alarmed or endangered. As soon as these appearances were noticed, it was immediately put into deep water, where it dived under at once and gradually recovered again. Then the gills always unfolded again. The

same experiment was made repeatedly and was every time attended by the same result; from which it may well be concluded that through the exercise of too energetic constraint with a view to hasten the process of transformation a stoppage may be brought about, and death, indeed, by continued constraint.

"Of Axolotl V. it remains to be stated that he crept out of the water, not like all the others at the *first* molt, but at the time of the *fourth*.

"All these are to-day alive, healthily and strongly developed, so that, as regards their nourishment, nothing would stand in the way of their propagation. The largest of the first four has a length of 15 centimetres. Axolotl V. measures 12 centimetres.

"From what I have said must be established the correctness of the view suggested in the beginning: most Axolotl larvæ, if not all, complete their metamorphose, if, in the first place, they come out of the egg healthy and are properly fed, and, in the second place, meet with arrangements which force them to change from breathing under water to breathing above the water. It will be understood that this compulsion may only be exerted quite gradually, and in a way which does not draw too much upon the animal's vital force.

"Freiburg, Breisgau, July, 1875.

"MARIE v. CHAUVIN."

I remark upon the above records, that in all five cases the change was a complete one, not to be confounded with that which all the Axolotls confined in small glass vessels undergo more or less; namely, there are frequently variations which seem to advance toward the Amblystoma form without reaching it. In the five full-grown Axolotls which I possess at this very time, and of which two at least are four years old, the gills are all very much shriveled up, but tail and crest are unchanged. But the crest may also disappear and the tail grow smaller without changing to the Amblystoma, as shall be shown further on. As regards the time used for the transformation, in Axolotls I. to V. it took 12 to 14 days. Four days of that bring us to the first change, during which the animal still remains in the water; the rest of the time is given to the completion of the change. Duméril gives the time of the transformation at 16 days.

From the experiments communicated the following seems to me especially noteworthy: *The five Axolotl larvæ*, which alone can come into the account, since the others died early, *all without exception completed the change and became Amblystomas.* Only one of them, No. I., showed by constant swimming on the surface, which was noticed at the end of the sixth month, a distinct inclination to the change, a preference for breathing with the lungs. Of this individual, therefore, it may well be assumed, that also without artificial aid it would have come to the land and have undergone the transformation, just as was the case in some thirty specimens which Duméril observed.

For Nos. II., III., and IV., on the other hand, such a supposition has but little probability. All three larvæ sought to keep themselves in deeper water, avoided as long as possible the shallow places which compelled them to mere lung-breathing, and only completed the change more than a month later.

With No. V., moreover, it can scarcely appear doubtful that it would not have made the change without the forcible habituation to abode in the air.

From these results may well be drawn the conclusion, most Axolotl larvæ change to the Amblystoma form if at the age of six to nine months they are brought into water so shallow that they must chiefly breathe with the lungs. The experiments in question are small in number, to be sure, but such a conclusion cannot be called hasty, when it is considered that Duméril, among many hundreds (the number is not given precisely) of Axolotls, obtained only some thirty Amblystomas; that likewise, among several hundred Axolotls, von Kölliker bred only a single Amblystoma.

It only remains doubtful whether every larva can be compelled to make the change, and this question can only be determined by new experiments. It had been my intention to defer the publication of those above given until they were repeated in greater fullness by Miss von Chauvin. But as my Axolotls have given me no young this year (1875), I had to give that up for the time, and could do this the more willingly, since it is rather irrelevant to the theoretical interest of the facts whether *all* or only *almost all* of the Axolotls may be forced to make the transformation. On the other hand, I will not forbear to mention, that the curator of the zoological museum here, Herr Gehrig, reared a considerable number of larvæ from the same brood, with which Miss von Chauvin experimented, and that of these larvæ six passed through the winter *without undergoing the transformation.* They were always kept in deep water, and therefore constituted the counter-experiment to those communicated above, showing that this whole brood by no means possessed a predisposition to undergo the transformation.

If, now, these new facts are to be made use of to clear up our conception of the nature of this unusual process of transformation, we must, before all else, bring to our aid the data already known.

In the first place, it is to be laid down that *Siredon Mexicanus, in its home, so far as we know, never undergoes the transformation. From that locality it is known only in the Siredon form.* The testimony which I find on this point comes from DE SAUSSURE,* who himself observed the Axolotl in the Mexican waters. This naturalist has never seen even a single Amblystoma in the vicinity of the lakes, and "yet the larvæ of the Axolotl are so common there, that they are brought into market by thousands." De Saussure believes that the Axolotl does not make the change in Mexico.

* Verhandl. d. Schweiz. Naturforsch. Gesellschaft. Einsiedeln, 1868.

Cope* asserts the same thing quite decidedly; and individuals bred by him in America from the *Siredon Mexicanus*, also in captivity, "showed no inclination to the transformation." On the other hand, Tegetmeier† saw the change begun in one of five individuals which traced their descent to the Lake of Mexico and so the second fact is established, *that also the genuine and real Axolotl under certain circumstances changes in confinement to an Amblystoma.*

This remark would be superfluous, if it were, as was long believed, true that the Axolotl of the Paris Garden of Plants, whose metamorphosis was first observed and excited so much attention at the time, actually belonged to the species *Siredon Mexicanus*, the only *Siredon* which in its home bears the name Axolotl.

In his first communication, Duméril himself was of this opinion; he called the creature "*Siredon Mexicanus*" syn. *Humboldii*;‡ but later, in his detailed work § on the change of the Axolotl contained in the Garden of Plants, he recalled this view, and, after a critical examination of the five described *Siredons*, came to the conclusion that the Axolotls in the possession of the Paris Museum were probably *Siredon lichenoides* Baird.

So all the transformations of Axolotls observed in Europe were to be referred to this species; for—at least so far as is known—they are all descendants of the Paris colony. Thence also, indirectly, came the subjects of my experiments.

To be sure, now it does not agree with this, that the Amblystoma form, which Duméril obtained from his Axolotls, corresponded with *Amblystoma tigrinum* Cope, while we learn by Marsh‖ that *Siredon lichenoides* Baird changes to *Amblystoma mavortium* Baird when it undergoes the complete metamorphosis. Marsh found the *Siredon lichenoides* in Alpine lakes (7,000 feet above the sea), in the southwestern portion of the United States (Wyoming Territory), and by breeding in aquariums obtained from it the *Amblystoma mavortium* Baird. Nevertheless, he holds it doubtful whether the animal ever goes through the change in its home; to be sure, without any sure foundation and on purely theoretical grounds, namely, because in his judgment "the colder temperature there is less favorable to it."¶

If I doubt the correctness of this last opinion, it is only because the *Amblystoma mavortium* in a state of nature has been found in many parts of the United States, namely, in California, New Mexico, Texas,

* Dana and Silliman, Amer. Journ., 3d series, i, p. 89. Annals Nat. Hist., vii, p. 246.

† Proceed. Zool. Soc. 1870, p. 160.

‡ Compt. Rend., tome 60, p. 765 (1865).

§ Nouvelles Archives du Muséum d'Hist. Nat. Paris, 1866. Tome ii, p. 268.

‖ Proceed. Boston Soc., vol. xii, p. 97; Silliman, Amer. Journ., vol. xlvi, p. 364; a reference to this in Troschel's Jahresbericht for 1868, p. 37.

¶ Proceed. Boston Soc., vol. xii, p. 97; Silliman, Amer. Journ., xlvi, 364. I could not examine these works myself, and quote from the reference in Troschel's Jahresbericht, 1868, p. 37.

Nebraska, and Minnesota. Nevertheless, it is by no means incredible that just in the Alpine lakes, from which Marsh obtained it, the species occupies a different position in regard to the transformation from what it does in other habitats. This will be seen from the observations on the Triton adduced below. So, until further observations are made, I believe we must suppose that the Paris Axolotls are not *Siredon lichenoides*, but probably a new and very closely related species.

Meanwhile, there is not much depending upon this in the review of the transformation, if it is only established that this Axolotl in its home does not undergo the metamorphosis, or only does it as exceptionally as in Europe. Unfortunately, there is in Duméril's communications no precise statement of the locality where this "Mexican" animal was found; probably the locality was unknown to himself, and so I can only assume on Cope's authority that no *Amblystoma* has ever been brought from south of the provinces of Tamaulipas and Chihuahua; that is, from south of the tropic.*

Of that, however, there is no certainty. Much more important is the fact adduced above, that the genuine Axolotl of the lakes around the city of Mexico never makes the change to an Amblystoma, but that this species also in isolated cases undergoes the transformation in confinement. Now, from this and from the fact that the Paris Axolotls in confinement are only transformed to the extent of a very small percentage, it may be concluded *that also in its home it is either not transformed at all, or only as an exception.*

But still another series of facts comes very essentially into the account in reviewing this history of transformation: I mean *the existence of a considerable number of species of Amblystoma in nature.* In the "Revision der Salamandriden-Gattungen" (Review of the genera of Salamanders) which Strauch † gave a few years ago, there are represented, according to the examples of Cope,§ *twenty* species of the *Amblystoma* Tschudi living in North America. Now, although a few of these species are based only upon *one* specimen, and, therefore, as Strauss correctly says, "must be suppressed in time," yet there is left a whole range of species which certainly live and propagate as Amblystoma, and which have their locality from the latitude of New York to that of New Mexico. *Hence there are certainly species of Siredon which, under their natural conditions of life, regularly take the Amblystoma form and propagate in it; while on the other hand there are at least two species which, under their present natural conditions of life, only propagate as Siredon.* It is only another form of expression for this fact when one says the Mexican Axolotl, and the Paris Siredon as well, be this latter named *lichenoides* or something else, stands *upon a lower phyletic stage of development* than the other species of Amblystoma which propagate in the salamander

* Dana and Silliman, Amer. Journ., 3d ser. i, p. 89; Annals of Nat. Hist. vii, p. 246.

† Proceedings Acad. Philad., xix, 1867, pp. 166–209.

§ Mem. Acad. Petersb., tome xvi.

form. No one can object to this statement; while the other proposition, either expressed or tacitly held by all authors, includes a theory which I regard as incorrect. That proposition is: The Mexican Axolotl has *remained* upon a lower phyletic stage of development.

All zoologists who have expressed themselves on the transformation of the Mexican Axolotl, and who are not, like its first observer, still attached to Cuvier's views on the immutability of species, took up the matter as if here was a species which through some sort of special circumstances had *remained behind* on a lower stage of development, and was now stimulated by some sort of influences to its *advance* to a higher stage.

For a long time also I did not believe that the thing could be otherwise understood, little as I was able to bring all the phenomena into harmony with this view. Thus in 1872 I used the following expressions:* "Why should not a sudden change in all the relations of life (the removal from Mexico to Paris) have had a *direct* influence upon the organism of the Axolotl, so that he *suddenly* attained a higher stage of development, which many of his kindred species have long since attained, which evidently lies in the nature of his organization, and which perchance he also would have reached in his native haunts, though at a later period? Or would it be too much to suppose that by the sudden transportation from 8,000 feet above the sea-level (the Mexican highland) to the altitude of Paris, the organs of respiration had received a shock which just brought them to the change already close at hand? So in all probability we have to do with a direct effect from altered conditions of life."

That the purport of the last sentence must also be held true to-day follows as a matter of course from the experiments communicated above, which surely prove that by the application of definite external influences we have to a certain extent it in our power to call forth the transformation. Just in that fact lies the new light which these experiments have brought.

But must we also understand the phenomenon in the manner above indicated—that is to say, as *a phyletic onward development of the species, appearing suddenly and in a measure resulting from a shock?* I believe not. What first perplexed me in regard to this view was the sight of my living Amblystomas reared from the larvæ of the Axolotl. These creatures by no means show a variation from the Axolotl in single traits merely, but they are distinguished from it in their entire habit; they differ somewhat in all parts; although slightly in many, in others quite decidedly; in short *they have become entirely different animals.* Corresponding to this they also live quite differently; no longer go into the water, but prefer in the daytime to keep hidden in the damp moss of their prison, and at night come forth to seek their food on the dry land.

*"Ueber den Einfluss der Isolirung auf die Artbildung" (On the Influence of Isolation upon the Formation of Species), Leipsic, 1872, p. 33.

To be sure I could have perceived the great difference between the two stages of development from the anatomical data long familiar to me which Duméril had given on the structure of his Amblystomas; but the reading over of many statements in detail gives no living picture. At any rate the sight of the living animal first brought me to the consciousness how comprehensive is the change we have to do with here; that by no means does it merely concern those parts which are directly affected by the alteration in the mode of life, but that most, if not all, parts of the animal undergo a transformation, which can be very well explained in part as the morphological adaptation to new conditions of life, in part as consequences of these adaptations (correlative changes), *but cannot by any possibility be explained in a word as the suddenly appearing effect of these changed conditions of life.* Such at least is my view, according to which a sudden development of the species, such as must have taken place here, is quite inconceivable. I willingly acknowledge that a few years ago the question whether such sudden development occurs was still an open one for me, but since then my investigations have kept urging me to the conviction that it does not occur at all, as I shall show in another place. Here I have to confine myself to the examination of this individual case; a case which appears to me—as was above intimated—quite peculiarly suited to shed light decisively upon the great alternative, about which at the present moment the war of opinions is centered, in regard to the doctrine of descent.

I may well assume that hitherto it has been with most students in regard to the metamorphosis of the Axolotl very much as with myself; it did not come to their consciousness *how far the transformation goes;* and so it may need to be made plain that the theoretical importance of the case and its value as a basis of inference was not properly emphasized by either side. But it is evidently a case of quite unusual significance for the principles involved. I believe it may be easily shown that the hitherto pretty generally admitted explanation of the history of the Paris Axolotl's transformation includes at the same time the recognition of a very far-reaching principle, namely: if this explanation were the correct one, then in my judgment would be at the same time demonstrated as correct the opinion of those who, like KÖLLIKER, ASKENASY, NÄGELI, and among the philosophers HARTMANN and HUBER, would refer the transmutation of the species in the first instance to a motive power dwelling within the organisms, to an active, *i. e.* spontaneous, "law of development," a "principle of perfection," or, as I should prefer to name it, a *phyletic vital energy*, in contrast to the exactly corresponding vital energy of the so-called "philosopher domain" in the nature of ontogenesis.

If, namely, the Axolotls that have become Amblystomas are to be taken as individuals which, stimulated by external influences, have hastened on in advance of the remaining individuals in their phyletic development, then this advance can only be placed to the account of a phy-

letic vital energy; for the transformation is a sudden one; it leaves no time for gradual adaptation in the course of generations. *Indirect* influence of the external relations of life, *i. e.* natural selection, is accordingly excluded from the first; but *direct* influence of the altered circumstances of life does not suffice by a great way to explain the total transformation of the whole structure, as I have already intimated and will now show more minutely.

The distinctions between the Paris Axolotl and its resulting Amblystoma are, according to DUMÉRIL, KÖLLIKER, and my own observations, the following:

1. The gills disappear, the clefts of the gills close up, and only the foremost of the arches of the gill remains in existence; the other arches vanish. At the same time the *Os hyoideum* is changed (DUMÉRIL).

2. The crest on the back disappears entirely (DUMÉRIL).

3. The rudder-like tail changes to a tail like a salamander's (DUMÉRIL), which nevertheless is not quite circular in section as in the salamander, but is somewhat compressed laterally (WEISMANN).

4. The skin gets yellowish-white patches, irregularly distributed on the sides and the back (DUMÉRIL), while at the same time its former ground color of grayish-black changes to a shining greenish-black (WEISMANN), and, besides, the shiny secretion from the skin is lost and the glands of the skin become indistinct (KÖLLIKER).

5. The eyes become prominent and the pupils small (KÖLLIKER), and eyelids are formed which can close the eye completely, while in the Axolotl only a narrow circular fold surrounds the eye, and it cannot be closed (WEISMANN).

6. The toes diminish in size and lose their skin-like appendages (KÖLLIKER), or, more precisely, the half web-membranes which unite the inner ends of the toes on all the feet (WEISMANN).

7. The palatal teeth in this, as in all Amblystomas, stand in a diagonal row, while in the Axolotl, like the Triton larvæ, they stand at the side of the palatal vault forming an arched band, with several rows of teeth.* (DUMÉRIL. See his figure. Zeitschrift f. wissensch. Zool., xxv Bd., Sup., p. 279.)

8. In the Axolotl the under jaw has, besides the teeth on the upper edge of the bone, some very small teeth disposed in several rows; these latter disappear after the metamorphosis (DUMÉRIL). I add that the permanent teeth belong to the *os dentale*, the temporary ones to the *os operculare*.†

* DUMÉRIL has the teeth of the vomer separated from those of the *os palatinum* by a gap. Probably this was an artificial one, as GAGENBAUR (FRIEDRICH & GAGENBAUR, "Der Schädel des Axolotl"—The Skull of the Axolotl—Würzburg, 1849) figures the rows of teeth without interruption, passing over from one bone to the other. The same was true in three Axolotls which I examined in regard to this point; moreover, this little difference is quite unimportant in the question here treated.

† See O. HERTWIG, "Ueber das Zahnsystem der Amphibien und seine Bedeutung für die Genesis des Skelets der Mundhöhle." (On the Dental System of the Amphibia, and its Significance for the Genesis of the Skeleton of the Mouth.) Arch. f. Mikroskop. Anat., Bd. xi, Supplementheft, 1874.

9. The posterior face of each vertebra is slightly hollowed out before as after the transformation, but the anterior face is less concave in the *Amblystoma* than in the *Siredon* (DUMÉRIL).

The details cited from DUMÉRIL under 7 and 9 I have not so far been able to confirm by personal examination, as I was not willing to kill any of my *living* Amblystomas, only for the purpose of verifying the details of a naturalist in whom perfect confidence may surely be reposed. In like manner, I have not yet seen the change in the arches of the gills. All the other data given by KÖLLIKER or DUMÉRIL I can corroborate completely.

The differences in structure which exist between Axolotl and Amblystoma are considerably greater and more important than those between neighboring genera, yes, greater than are found between the *families* of the *Urodela*. The genus *Siredon* without any doubt belongs *to a different suborder* from the genus *Amblystoma*, into which it is occasionally transformed. STRAUCH, who has made the latest arrangement of this group, separates the suborder of the *Salamandrida* from that of the *Ichthyodea* by the possession of eyelids and by the position of the palatal teeth in a simple row on the posterior edge of the palatal bone; while in the *Ichthyodea* the lids are wanting and the palatal teeth either "stand on the front edge of the palatal bone or cover the whole surface of the palate as brush-like clusters." How would it be possible now to regard anatomical characters standing so far asunder as transformations which had been suddenly called forth by a single operation of varying conditions of life?

Hand in hand with the falling out of the old palatal teeth and the appearance of new goes a change in the anatomical structure of the vertebral column, and, as we may conclude from KÖLLIKER'S entirely accurate observation on the stoppage of the slimy secretion from the skin, in the histological structure of the skin itself.

Who would undertake to explain all these deep-lying changes as the direct and sudden effect of any external influences whatever *operating but once?* And even if any one had an inclination to explain them *as results of the loss of the gills*, and therefore as *correlative changes*, what would such a *correlation* be but the newly-christened vital energy above spoken of? For if from *one* variation caused by direct influence of *external* agencies the whole body can through correlation transform itself in a couple of days just so in all its parts *as it appears best adapted for the new conditions* of life in which it is henceforth to be, then the word correlation is only a term, by which nothing is explained, but the search for a better explanation is hindered. Then it is preferable that we simply acknowledge our belief in a phyletic vital energy.

Moreover it certainly is not allowable even to wish to seek an explanation of that sort (by correlation), *for we know some Urodela in the adult state have no gills, and yet possess all other marks of the Ichthyodea:* lack

of the eyelids, characteristic type of the palatal teeth, and of the arrangement of the lingual bones. Such are the genera *Amphiuma* L., *Menopoma* Harl., and *Cryptobranchus* v. d. Hoev. The first two genera, as is well known, still have the clefts of the gills. *Cryptobranchus*, on the contrary, has lost these clefts, which are grown over with skin as in the *Amblystoma*, and yet, by the unanimous testimony of all systematic zoologists, it is a genuine fish-lizard in habit, arrangement of the lingual bone, palatal teeth,* &c. It must be added *that even the Axolotl itself may lose the gills without, on that account, changing to an Amblystoma.* I have mentioned elsewhere that in Axolotls which are kept in water that is shallow and still, the gills frequently grow small; but it also happens that they shrivel up entirely. I have an Axolotl preserved in spirits, in which the gills are shriveled to little irregular bunches; at the same time the crest on the back is so completely wanting that a longitudinal furrow has appeared in its place, and on the tail the border of skin has entirely vanished from the lower margin, and about half from the upper. Nevertheless, the animal is widely separated in structure from the Amblystoma: it has the arches of the gills, the palatal teeth, the skin, &c., of the Axolotl.

This demonstrates, therefore, that the loss of the gills by no means must always bring after it all the other variations which we see take place in the metamorphosis of the Axolotl; that these, therefore, are by no means the necessarily and immediately appearing result of that loss. Whether they must necessarily appear after long successions of generations, whether also the descendants of *Cryptobranchus* will some time in the future take the structure of the *Salamandrida*, that is another question which I should not like to answer just in the negative, but which does not come into the account here, as we are considering only a possible *sudden* result from the loss of the gills.

The question, therefore, seems to stand thus: *Either our apprehension up to this time of the transformation history of the Axolotl as a further development of the species is incorrect, or the existence of a phyletic vital energy is demonstrated by the case of the Axolotl beyond the possibility of a refutation.*

Now the question comes up, whether the facts of this transformation history do not also admit of another explanation. I believe that this is at any rate possible and that another interpretation may be shown as the correct one with a good degree of probability.

I esteem those Amblystomas which in individual cases have developed in confinement from Siredon Mexicanus (syn. pisciformis), as well as from the Paris Axolotl, not as forms of advancement, but forms of retrogression. I believe that the Axolotls which to-day live in the lakes of Mexico were already Amblystomas a geological (or better a zoological) epoch earlier, but

* See Strauch, Zeitschrift. f. Wissensch. Zool., xxv Bd., Suppl., p. 10.

that through alterations in their conditions of life they have sunk back to their earlier stage of the Perennibranchiates.

Without doubt I was first led to this intepretation by the results I had reached in my studies on the season-dimorphism of butterflies.* There also we have the question of two different forms under which one and the same species appears, and of which it may be proved as probable that one is phyletically the older, the other the younger. The younger summer form has in my view proceeded through the gradual warming of the climate from the winter form that in an earlier zoological epoch was the only one; but this latter, the primary form, has not on that account ceased to exist, but to-day still alternates every year with the secondary, the summer form.

Now it is easy with the season-dimorphous butterflies to make the summer brood assume the winter form, and that by exposing their pupæ rather a long time to a lower temperature; and it may be made in the highest degree probable that this suddenly appearing variation or transformation, often very far reaching, is sudden in appearance only, and is but apparently the result of cold acting upon this generation. Much rather in truth the variation depends upon a reversion to the primary form of the species, and therefore the cold that appears but once is only the *impulse to the reversion*, but not the *true cause of the transformation*. This cause must be sought in the long-continued operation of the cold, to which thousands of generations of the ancestors of our living butterflies were subjected, and whose final result was just the winter form.

If we now assume for a moment that my interpretation of the Axolotl's transformation-history as just given is correct, we have relations here which are in many respects analogous to those of the season-dimorphism. To be sure the two forms in this case no longer alternate regularly with each other, but the primary form may occasionally appear in place of the secondary, and this result from the shock of external circumstances. As *there* we succeed in stimulating the summer brood by the action of cold to lay aside the summer form and adopt the winter dress, so *here* we are able to lead the Axolotls into the Amblystoma state by compelling them at a certain age to breathe air.

Further, as in the season-dimorphism, it may be shown that this transformation called forth by artificial means is *only in appearance* a sudden new formation, but in truth a reversion to the much older winter form, so here we also had to do, not with an *actual* new formation of the species, but only with an *apparent* one, a reversion to the phyletically older form of the species. To be sure that sounds very paradoxical if here is a form that must have come by reversion, and yet it must undoubtedly be accounted as the *more highly* developed. But I believe

* Studien zur Descendenztheorie, I. Ueber den Saison-Dimorphism der Schmetterlinge (Studies on the Doctrine of Descent, I. On the Season-Dimorphism of Butterflies), Leipsic, 1875.

that on more careful consideration much of the paradox which seems to lie in this view will disappear.

Before all else, it is to be considered that the phyletic development of the species need by no means have always gone directly forward. We have examples enough of development backward, although in rather a different sense, as in parasites and such forms, which have sunk from free locomotion to the sedentary mode of life. I do not ignore the difference which exists between this sort of development backward by the pining away of certain organs or systems of organs, and proper reversion. The latter is *the return to an animal* form *already once existent*, but in the former case, in spite of all simplification of the organization, *something wholly new* is always formed. But I am able to see nothing absurd as to principle in the supposition that a proper reversion, also, be it of a whole species or of the individuals of a species within a certain habitat, is thought of as *possible*, and I do not for the present demand a further concession. Why, for example, should it be so entirely incredible that the Axolotl, in a time long past, was adapted to living on the land, that it *gradually*, through direct and indirect operation of altered conditions of life, had acquired the salamander form, but that later, by a new change of the circumstances of life unfavorable to its present organization, it has again fallen back into the old form or one lying near it? At any rate, such a supposition contains nothing which would stand in contradiction with well-known facts, but can be sustained in several ways; and finally, it recommends itself by furnishing, at least in my opinion, the only possible explanation of the facts before us.

The above-mentioned existence of a whole group of species of *Amblystoma* shows at once that species of *Siredon* can rise to the salamander form, and can regularly propagate in that form; and further, that this phyletic advance has already actually taken place in very many species. But that a sinking back from this higher stage of development to the lower can also take place, several observations on our water salamanders show.

It is well known that Tritons under some circumstances become, as it is usually expressed, "sexually mature in the larval state."

In the year 1861 De Filippi* found in a swamp by Lake Maggiore fifty Tritons, of which only two showed the structure of the full-grown water salamander; but all the others still had their gills, yet corresponded to mature animals in bodily size and in the development of the sexual organs, and that in both sexes.

Filippi determined the fact that these "sexually mature larvæ" did not merely resemble larvæ externally by the possession of gills, but that they also presented all the other anatomical marks of the larvæ; that is, the characteristic clusters of palatal teeth standing on both sides, instead of the later simple row, and a vertebral column, which still has the *Chorda dorsalis* running through its whole length.

* Sulla larva del Triton alpestris, Archivio per la Zoologia, 1861.

According to my view this would be *a case of reversion of the Triton to the phyletic stage lying next behind it, that is, the Perennibranchiate stage;* and in this case most zoologists who stand at all upon the footing of the doctrine of descent will agree with my view. I at least would count it a profitless playing with words if any one should speak here of larval reproduction and believe he had thereby explained anything. In any event the animal becomes sexually mature in the condition in which it first appears as a larva. But we first get an insight into the nature of this phenomenon by the reflection that this so-called "sexually mature larva" has precisely the structure which the preceding phyletic stage of the species must have possessd; that therefore we have a reversion of the individual to the older phyletic stage of the species. I esteem it an error when DUMÉRIL puts this case of the Triton in parallel with the genuine larval reproduction of WAGNER'S *Cecidomyia* larvæ. There it is certainly not reversion to an older phyletic stage which makes the larvæ capable of reproduction; for these larvæ present no older phyletic stage of the species, but *must have arisen at the same time with the species in its present form.* The vast difference in the structure of the larva and the fly is not explained by assuming that the latter has arisen from the former as from a finished given quantity, but by this, that both at the same time have adapted themselves to conditions of life further from each other.* Regarded phyletically, these larvæ are not at all a necessary point of transit for the origin of the fly. They could also be built quite otherwise, without the form of the fly needing to be likewise changed; for the stages of insect transformation vary independently of each other, corresponding to the conditions of life to which they are subjected, and exert no influence upon each other, or only a very slight one, in the determination of form, as I shall attempt to demonstrate in another place. At any rate, "the ability of these larvæ (the *Cecidomyia*) to multiply asexually has first been acquired as a secondary matter, as already follows from the fact that there are numerous species of the same genus of flies which do not feed their young." "In the form which they possess to-day they can never have played the part of the final stage of ontogenesis, and therefore also cannot have possessed at a former time the power of sexual reproduction.† In short, we have to do here with genuine larval reproduction, but in the Tritons with reversion to an older phyletic stage.

Nor can I agree with my friend HAECKEL, when he designates the reversion of the Tritons as "adaptation to continued life in the water."‡

One would only be able to speak of "adaptation" in this case by taking the word in a sense quite different from that with which DARWIN

* Compare, also, LUBBOCK, On the Origin and Metamorphoses of Insects. London, 1874.

† See my paper "Ueber den Saison-Dimorphismus der Schmetterlinge," Leipsic, 1875, p. 60.

‡ See HAECKEL'S Anthropogenie, p. 449.

and WALLACE have introduced it into science. Those naturalists distinguished by the word a gradual remodeling of the body, taking place in the course of generations, corresponding to the new demands of new conditions of life; in other words, the operation of natural selection, but not a result from causes of variation suddenly and directly acting once and in one generation.

Just because the word "adaptation" may, according to customary use of language, be used in many different senses, it would be desirable to take it only in *one* acceptation and to have that fixed exactly; before all, not to speak of adaptation when there is no *morphological* change, but only a sort of exchange of functions in DOHRN'S sense.* Thus, for example, when FOREL† shows that fresh-water air-breathing snails, whose organization is calculated for the direct breathing of the air, could nevertheless pass to the greatest depths of the Alpine lakes, while they used their lungs as gills. That with this not the slightest change has taken place in the lungs, is shown by the observations of v. Siebold.‡

He saw the Pulmonates of shallow water use their lungs alternately for direct air-breathing and for water-breathing, according as the atmospheric contents of the water was less or greater. If with v. Siebold one should apply the word "adaptation" simply to such cases, it would lose the special sense which was originally attached to it; as a technical term the word would have to be given up.

At any rate, there is as little a case of genuine adaptation in the Triton "larvæ" that were capable of reproduction as in the Axolotl exceptionally changing to the Amblystoma. In both cases, also, the transformation in consideration is not at all indispensable *for the life of the individual.* Mature Tritons (without gills) live, as I have witnessed, many months, probably for years, in deep water, although they are fitted for simple air-breathing; and Axolotls, as I have already stated above, can live quite well for years in shallow and quiet water. If their gills shrivel, yes, vanish entirely, this also yet is no adaptation in the Darwinian sense, but a direct result of external influences, principally indeed of diminished use.

A case quite analogous to FILIPPI'S was observed in 1869 by Jullien. Four female larvæ of *Lissotriton punctatus* Bell. (synonym for *Triton tæniatus* Schnd.) were fished out of a swamp and showed themselves sexually mature. In their ovaries they had matured eggs, ready for laying, and two of them also actually laid the eggs. Four male larvæ, which were taken in the same swamp, showed themselves likewise developed in regard to bodily size, though they had no spermatozoa in the testicles, but only sperm-producing cells.§

* "Der Ursprung der Wirbelthiere und das Princip des Functionswechsels" (The Origin of the Vertebrates and the Principle of the Exchange of Functions). Leipsic, 1875.

† Faune profonde du lac Léman; Verhandl. d. Schweiz. Naturforsch. Gesellschaft (Deep Fauna of Lake Geneva). Schaffhausen, 1873.

‡ Zeitschrift f. Wissenschaftl. Zool. (Journal of Scientific Zoology), bd. xxiii, 1873.

§ Compt. Rend., t. lxviii, p. 938, 939 (Proceedings of the French Academy of Sciences).

A third case of the same kind I find cited* by SEYDIG, in his essay, "Ueber die Molche der Würtembergischen Fauna" (On the Salamanders in the Fauna of Würtemberg), so rich in interesting detail. SCHREIBERS, the former director of the Vienna Cabinet of Natural History, likewise found "larvæ" of Triton with gills well developed, but of the size of "adult males," and, as anatomical examination showed, with well developed sexual organs, as well as ovaries filled with eggs.

So, therefore, it is established that species which long ago attained the stage of Salamandrida in the phyletic development may occasionally sink back to the stage of Perennibranchiates. Evidently, this fact makes my view of the Axolotl as a form of reversion appear much less paradoxical. Indeed, the cases of reversion in the Triton are directly analogous to the transaction I suppose for the Axolotl.

We only need suppose Amblystomas in the place of the Tritons, and consider the swamp in which DE FILIPPI found his "sexually mature Triton larvæ" expanded to the Lake of Mexico, regarding, also, the unknown, and perhaps in this case temporary, causes of the reversion as permanent, and we have everything which is necessary to the restoration of the Axolotl as we know it to-day, *we obtain a Perennibranchiate population of the lake.*

It is not even yet determined whether, in that swamp of DE FILIPPI the Perennibranchiate form of the Triton does not actually prevail *permanently*, for it has not, to my knowledge, been examined since in regard to this subject.

But if we assume for a moment that it actually were so, that a colony of Perennibranchiate Tritons lived there, carrying on reproduction sexually, should we wonder if occasionally, also, a genuine Triton came from our brood, if we could succeed in stimulating most individuals of this brood by removal into shallow water to the metamorphosis into Tritons? But just so it is according to my view with the Mexican Axolotl.

But I need not limit myself to support my hypothesis, but must also directly assail the tenability of the one hitherto held, for it stands in opposition to facts.

If we really had in the Axolotl a suddenly occurring phyletic further development, then one fact would remain wholly incomprehensible, namely, *the sterility of the Amblystomas.*

Of about thirty Amblystomas which Duméril had obtained up to the year 1870, full sexual maturity had not appeared in a single one; neither copulation nor the simple laying of eggs had taken place, and the individuals that were examined anatomically showed the eggs immature and the spermatozoa present indeed, but without the undulating membrane belonging to all the Salamandrida. They were not destitute of all power of motion, but as QUATREFAGES stated, only moving imperfectly.†

* Archiv f. Naturgeschichte (Archives for Natural History), 1867.

† Compt. Rend., t. lxx, 1870.

The five Amblystomas, on which I have reported here, have shown, up to the present time, no appearances of reproduction.

It is evidently an objection that will very poorly stand the test when SACC* attributes the sterility of the Amblystomas reared from Axolotls to "poor food." Why, then, do the Axolotls reproduce so easily when they are fed exactly the same? I can also state expressly that my Amblystomas are quite excellently fed. To be sure, these have hardly reached the age of one and a half years; but the Axolotls propagate the second year, and some of DUMÉRIL'S Amblystomas were five years old in 1870.

The fact of sterility stands in clear opposition to the view that these Amblystomas are the regular advanced guards of the genus Siredon as it moves forward in phyletic development. To be sure I will by no means maintain that my theory of reversion could actually explain the sterility, but at least it does not stand directly in contradiction with it. Mere forms of reversion may perish without reproducing themselves. A *new* form called forth by the working of an unknown phyletic vital energy cannot be a sterile one, because this directly destroys again the "purpose" which the vital energy is pursuing. The idea of the vital energy includes that of teleology.

Moreover, from our stand-point the sterility of the Amblystomas may be, if not completely understood, yet shown as a phenomenon that does not stand quite alone. In the case of the *Lissotriton punctatus*, as quoted above, the *female* "larvæ" were at any rate sexually mature and laid eggs, but at the same time the *males* had no perfected spermatozoa in the testicles.

Other cases of the kind are not known to me. At the time when I made my experiments with butterflies, as mentioned above, this point of view was still unseen, and so I neglected to examine the artificially produced forms of reversion in regard to their organs of generation. But general principles also lead to the conclusion that atavistic forms may easily remain sterile.

DARWIN* finds the most immediate causes of sterility, first, in the operation of widely varying circumstances of life; and, second, in the crossing of individuals with widely differing constitutions. Varying circumstances of life are at any rate what induce the transformation of the Axolotl, and from this point of view it could not be surprising if we find those individuals sterile, which have precisely shown themselves as especially affected by these altered conditions of life, since they have reverted to the salamander form. In this reasoning it is by no means asserted that *reversion always and without exception* is accompanied by sterility. Nor can it be objected to my interpretation of the Axolotl's transformation that through reversion a colony of Axolotls capable of reproduction never could have arisen. On the contrary, JULLIEN'S female Triton

*Bull. Soc. Neuchâtel, Bd. viii, p. 192, a reference to the place in Troschel's Jahresbericht (Annual Report), for 1869.

*Origin of Species, 5th edition, p. 325.

larvæ that laid eggs exactly prove that even in reversion the power of reproduction may remain complete. From the universal causes of sterility mentioned above, it may be inferred that through those causes fruitfulness may be lost in *different* degree; and, further, it may in a measure be understood why the fruitfulness is more completely lost in the reversion to the Amblystoma form than in the reversion of the Triton to the Perennibranchiate form.

If in these cases the reversion is called forth by altering the conditions of life, one may perhaps imagine that the extent of this alteration will also fix the degree of fertility which the atavistic form can preserve; but still more will the fertility be influenced by *the extent of the morphological skip* which is made in the reversion.

We know that the blending of widely varying constitutions (*e. g.*, in the crossing of different species) produces sterility. Something similar takes place also in the sudden reversion to a stage of development widely varying in its whole structure. Here also takes place to a certain extent the union of two very different constitutions in *one* individual, a sort of crossing.

From this point of view it may be, to some extent, understood why sterility may be a result of the reversion, but, on the other hand, we obtain no explanation why with the same breadth of morphological variation there occurs in one case complete sterility, in the other relative fruitfulness. The extent of the morphological contrast is exactly the same between Axolotl and Amblystoma as between Triton and its "sexually mature larvæ." The difference in the two cases of reversion lies entirely in the direction of the skip, which in the first case is made exactly in the contrary direction to that in the second.

Just in that I would seek the reason for the varying force with which the power of reproduction is affected; not in the direction of the leap *in and for itself*, but in the differences of the ontogenesis, which are conditioned upon the direction of the leap.

The *reversion* of the Triton to an *older phyletic stage* coincides with *remaining* upon a *younger ontogenetic* stage; or, in other words, *the older stage of phylogenesis, to which the reversion takes place, is still entirely included in the ontogenesis of every individual.* Every Triton is a Perennibranchiate for a considerable portion of its life; the individual that makes the reversion simply reverts to an older phyletic stage by remaining in the larva stage of its individual development.

Quite otherwise with the reversion of the Axolotl to the Amblystoma form, which had been once reached at some former time, but long since given up. *This is not included in the ontogenesis of the Axolotl, but has entirely fallen out.* For a long succession of generations—so we must suppose—the ontogenesis has always proceeded only to the Perennibranchiate form. If now single individuals are made to revert to the Amblystoma form, no greater leap in respect to morphology is made than in the reversion of the Triton to the Perennibranchiate form. At

the same time it involves a leap in an opposite direction, namely, a leap away over a long succession of generations, back to an animal form, which for a long time the species had not produced, which to a certain extent had become foreign to it.

We should therefore have here also the coincident effect upon the Axolotl's constitution of a widely different constitution, or—if one prefers—the blending of two widely varying constitutions.

Of course I am very far from wishing to give this explanation for an exact one. It is nothing more than an attempt to point out the force in which we are to seek for the cause of the varying extent to which the power of reproduction is affected. To investigate more deeply and to demonstrate specially in what manner this force comes into operation must be left to a later time. For the present it must suffice to have shown in this connection that in general an essential difference exists between the two kinds of reversion, as well as to have made it in some measure comprehensible that this difference may be the motive force in relation to the question of sterility. Perhaps the law involved here may some day be formulated thus: *Atavistic individuals lose the power of reproduction the more completely as the series of generations of their ancestors is longer whose ontogenesis no longer contains the phyletically older stage to which the reversion takes place.*

Consequently our hypothesis, which regards the transformation of the Axolotl as a reversion, offers us at once the possibility of learning to understand the sterility of the Amblystomas produced from Axolotls. So on the contrary the observed sterility of these Amblystomas is for those who think that a phyletic vital energy was here exerted—let it be named whatever it may—not only "a veritable scientific enigma," as DUMÉRIL expresses himself, but a complete parodox. Of such a designing, impelling principle it ought to be expected that it would bring forth new forms capable of life and not decayed to the point of dying out; and this so much the more since there is concerned a combination of structural peculiarities, which, when it has originated in another way (namely, from other species of *Siredon*), *has already long ago shown itself capable of life and reproduction.* We know species of Amblystoma which reproduce as such, and every one of which comes from a larva like the Axolotl. One cannot, therefore, explain the sterile Amblystomas which the Paris Axolotl produces as an unsuccessful effort of the vital energy—an explanation, which to be sure, would be in and for itself sufficiently presumptuous.

But now it may be asked, *What change in the conditions of life could it have been* which made the *Amblystoma in the Lake of Mexico** revert to the Siredon form? To be sure, I can only answer this question with conjectures, which can claim but a limited value so long as they cannot be sustained by a more exact knowledge of the circumstances there and the habits both of the Axolotl and the Amblystoma.

*As we do not know the origin of the Paris Axolotl, I must confine myself in the following to *Siredon Mexicanus* Shaw.

In general it may be presumed *that the same external influences demanded the reversion which at an earlier time called forth the formation of the Perennibranchiate stage.*

In favor of this conjecture we may adduce the experiments here communicated, for evidently it is the stimulus of the air breathing which brings the young Axolotls to the reversion to the Amblystoma form, *i. e.*, the same stimulus under whose dominating influence the Amblystoma form must have arisen.

But the case is quite similar with the season-dimorphous butterflies. There a reversion of the summer brood to the winter form is most easily called forth by the operation of cold, *i. e.*, by the same influences under whose control the winter form was developed. We know, at any rate, that reversion may arise also from the crossing of races and species, and I sought to show that reversion in butterflies may also be called forth by other influences than cold. But the most probable presumption is evidently the one that the reversion was induced through a recurrence of the same cause which to a certain extent produced the Perennibranchiate form. That this form has been shaped under the influence of life in the water admits of no doubt; and so my conjecture is that the hypothetical *Amblystoma Mexicanum*, the supposed ancestral form of the present Axolotl of the Lake of Mexico, *must have been brought to revert to the Perennibranchiate form by the circumstance that the possibility of going on land was taken from it and it was constrained to stay in the water.*

I will not reject beforehand every other opinion. We must carefully distinguish between the mere provocations which are able to produce sudden reversion and *actual causes of variation* which have for their result, directly or indirectly, the molding of a species. So it would not be inconceivable *a priori* that reversion should occur through the working of an impulse which has nothing to do with the *origin* of the phyletically older form. Certainly temperature has had no share, or only a very slight one, in the fashioning of the Perennibranchiate form. Yet cold, in and for itself, might quite well be one of the provocations which one day caused the Amblystoma form to revert to the Siredon form; and one could not *a priori* contradict DE SAUSSURE when he expresses the opinion that the low temperature of the Mexican winter must hinder the transformation (of the Axolotl to the Amblystoma) which had taken place "in the hot reptile room" of the Paris Jardin des Plantes. He supports his view by the fact that "TSCHUDI has found the Amblystoma" (of course another species) "in the hottest part of the United States." "On the plateau of Mexico, however, it snows every winter; and although the lake does not freeze, its temperature must sink very low near the surface."

But although no theoretical considerations oppose this view, yet I do not think it correct. I question very much that it was the temperature which induced the change from the Amblystoma back to the Axolotl,

or—according to DE SAUSSURE'S explanation—which at the present hinders the transformation of the Axolotl in the Lake of Mexico. This is the reason for my doubt: From all portions of the United States to the northward of New York Amblystomas have been collected; a proof that even a much greater degree of winter cold than that found on the plateau of Mexico is no hinderance for the transformation of the Axolotl; that the genus does not prove more sensitive in this respect than our native genera of *Salamandrida*.

More consideration seems to me to be deserved by the following remarks of DE SAUSSURE, in which he points out the character of the Mexican lake: "The bottom of this lake is flat, so that one comes imperceptibly from the lake to wide, swampy regions before he reaches firm ground. Perhaps this condition makes the Axolotl unable to get to the dry land, and so hinders the transformation."

At any rate the Lake of Mexico offers very peculiar conditions of life for an amphibious animal. My esteemed friend, Dr. V. FRANTZIUS, called my attention to it that this lake, like many others also of the Mexican lakes, is brackish. At the time of the conquest of Mexico by Ferdinand Cortez this circumstance caused the final surrender, as the Spaniards cut off the water from the besieged and the lake water is not drinkable. The old Mexicans had already built conduits from the distant mountains, and at the present day the city is still dependent on the water brought in by aqueducts.

Now, this saltness, in and for itself, could be no cause for the falling back to the Perennibranchiate form, but might be such a cause, in connection with other peculiarities of the lake. The shallowest part of the lake is the *eastern*, and only in this part does the Axolotl live. In the winter violent storms from the east blow regularly and persistently, which come down from the mountains and drive the water before them so powerfully that it rises in the western part of the lake and frequently causes overflows there, while from the flat eastern shore the bottom is laid completely dry for 2,000 feet.* Now if one puts together these two peculiarities, the salt and the periodical drying of a part of the lake-bottom by continued winds, he gets at any rate conditions of life for the Axolotl such as can be found in very few other places. To be sure, one might attempt to turn them to use just in an opposite sense, unfavorable to my theory, for the withdrawing of the water from a great part of the lake bottom ought—so might one think—rather to make easier the animal's transition to living on the land; yes, just compel it thereto. But one forgets, however, that the bared lake-bottom *is a sterile plain*, without food and without hiding-place; above all, without vegetation; and further, that through the pretty considerable saltness of the water (specific gravity, 1.0215) all the surface laid dry must be covered with a crust of salt, a condition which will make feeding on the land just impossible.

* Mühlenpfordt, Versuch einer getreuen Schilderung der Republik Meijco, Hanover, 1844, ii, p. 252 (Attempt at a true Picture of the Republic of Mexico).

Chloride and carbonate of soda, chiefly, are dissolved in the water in so sensible a quantity that they are regularly precipitated as a crust on the shore of the lake, and this crust is gathered there during the dry season and comes into the market under the name of tequisquite.

So, therefore, there is no lack of points of support for the conjecture that peculiar circumstances made life on the land more difficult to the animal than life in the water, and this alone might have been sufficient to bring it back to the habit of water-life only, and with that also to the reversion into the Perennibranchiate or Ichthyodea form.

Yet a truce to conjectures. We cannot lament that from the great distance and lapse of time, we are not in the condition to ascertain with definiteness the causes which compelled the Axolotl to give up the Amblystoma stage, so long as we are not able to solve the case of reversion that lies much nearer to us in the Tritons of FILIPPI and JULLIEN. Yet here, also, universal causes affecting the whole colony of Tritons must have been at the foundation, since, at least in FILIPPI'S case, the great majority of the individuals remained in the larva state. It must be that experiments with Triton larvæ would bring greater clearness here; they would have to determine, before all else, whether the reversion can be called forth artificially, and, if this is the case, through what influences.

According to the above-quoted experiences with butterflies, as well as according to the results attained with Axolotls, we should have to expect with the Tritons that the reversion to the Ichthyode form would occur if one would continue the stimulus of the water bathing the gills and the whole body, and at the same time would take away the stimulus under whose operation the *Salamandrida* form has been fashioned—the stimulus of the air bathing the gills, the skin, and the lungs. I hope at a later time to be able to report on experiments of this kind.*

No one will wish to object to my hypothesis of reversion, that on one side it opposes what it of itself postulates on the other side: *a sudden change of structure.* The characteristic of the reversion is precisely in reaching at a bound an older, that is, an earlier existing phyletic stage. That this occurs is a fact; while the reaching at a bound, to express myself figuratively, of an aim (pardon the word) that lies forward has never yet been proved or even made probable.

But as we succeeded in finding in the Axolotl's present conditions of life-forces which make its life on the land difficult or quite impossible, and therefore show a motive for that return to the Ichthyodea form which seems to have taken place; so can the other side of my hypothesis

*At any rate, SCHREIBERS seems, in his essay already cited above, to have communicated experiments from which it follows, as LEYDIG recapitulates them in the place referred to, that the last change, *i. e.*, the loss of the gills, "may be delayed by forcible means." To be sure, it does not follow from this that the animals of the experiment also became sexually mature at the same time. Unfortunately I could not myself examine the paper, as the volume of the Iris for 1833, as referred to, contains nothing of the kind, and I have lived for a long time at a distance from any large library.

be supported by facts, namely, the assumption that the ancestors of the Axolotl had at an earlier time already been Amblystomas.

We know from HUMBOLDT * that the surface of the Lake of Mexico once lay considerably higher than at present, and that in a time comparatively modern. We know, further, that the plateau of Mexico was covered with forest, while now the forest has vanished where the settlements of man, especially of the Spaniards, have reached. Now, if one may suppose that somewhere about the diluvial epoch the mountain forest extended to the edge of the lake, then still deep and with abrupt shores and containing considerably less salt, we have indicated conditions of life not only different essentially from the present ones, but also such as were quite specially favorable for the shaping of a species of the Salamandrida.

In the light of all this I believe people will not be able to cast upon my attempt to explain the exceptional metamorphosis of the Axolotl from the Lake of Mexico the reproach of being too free a flight of fancy. *At any rate it is the only possible explanation* which can be opposed to that other one which assumes that the occasional transformation of the Axolotl is not reversion, but an effort to advance. And this assumption must, in my estimation, be rejected on purely theoretical grounds by every one who thinks a *sudden* transformation of species *inconceivable, at least when it is joined with adaptations to new conditions of life.* That assumption must be rejected by every one who looks upon adaptations not as the work of magic arising at a stroke, but as the final result of a long succession of natural causes, though separately slight and imperceptible.

Should my interpretation of the facts be correct, this history of transformation would not have a significance so far-reaching as if it could have been taken in favor of heterogeneous creation, namely: in that case, demonstrating the existence of heterogeneous creation, it would have settled the question between that and transmutation. Now, on the contrary, it brings no definite decision, because, strictly taken, the refutation of sudden transformation in *one* case only proves it as not present for this *one* case.

But it is, after all, a contribution to the gradual and complete rejection of such sudden transformation. If one case after another which seemed to speak for heterogeneous creation is proved untenable on that theory, the argument by induction must finally acquire sufficient strength to be acknowledged as satisfactory.

If my view of the facts is correct, a few corollaries result from it which here at the close I should like to mention briefly.

First, a thing that is more external:

If the *Siredon Mexicanus* Shaw only assumes the Amblystoma form by occasional reversion, but never reproduces as such, but only as *Siredon*, we cannot approve the action of the latest writers on systematic zoology, who simply strike the genus *Siredon* out of the system, and

*See Mühlenpfordt's book already quoted, vol. i.

bring in the *Siredon Mexicanus* as an unwelcome addition under the genus *Amblystoma*. So long as there are not *one* only, but *several* species of *Siredon* on the earth, which are regularly reproduced *as such* and only as such, so long the genus exists. And if we would not quite rob the systematic writers of the hope that some time these species of *Siredon* would rise to be *Amblystomas*, yet it corresponds better to the state of things now existing on the earth if we still allow the genus *Siredon* to stand among the genera of fish-salamanders and reckon in it all those species which, like the Paris Axolotl, the *Siredon Mexicanus* Shaw, and probably also *Siredon lichenoides*, only take the Amblystoma form as an exception or by artificial influences, but without reproducing themselves in it.

On the other hand, all those species may probably be added to the genus Amblystoma which reproduce in this state, and in which the Perennibranchiate stage appears only as a larval condition.

To make this distinction in the individual case will be chiefly the task of the American naturalists, from whose ever-increasing activity we may hope indeed for fuller details on the reproduction of the numerous species of *Amblystoma* in their native land. I should rejoice if my explanations here presented should give an impulse to such investigations.

The second corollary to which I referred is of a purely theoretical nature. It concerns an addition to the "*fundamental law in the genesis of life*," first set forth by Fritz Müller and Haeckel. It is well known that this is stated in the following proposition: The Ontogenesis contains in itself the Phylogenesis, more or less contracted, more or less modified. Although the proposition cannot be rigidly proved, because we have no means of seeing the phyletic development directly unfolded before our eyes, yet its correctness and general validity can be made so highly probable, in an indirect way, that few naturalists of the present time doubt it who have occupied themselves with the history of development and comparative morphology.

Now, according to this proposition, every stage of the phyletic development, when it is displaced by a later one, must remain included in the Ontogenesis, and therefore come to light in the form of an ontogenetic stage in the development of every individual. Now, with this my explanation of the Axolotl's transformation appears to stand in contradiction, for the Axolotl which had in former generations been an *Amblystoma* contains nothing of the *Amblystoma* in its Ontogenesis. Nevertheless the contradiction is only apparent. *As soon as a further development is actually in question*, and therefore the attainment of a new stage not yet realized, so soon the older stage is taken up into the Ontogenesis. But it is not so when the new is not actually new, but has at a former time presented the final stage of the individual development, or, in other words, when there is a *reversion*, not of the single individual, but *of the species as such* to the preceding phyletic stage, and, therefore, a phyletic sinking back of the species. *In this case the final stage of the Ontogenesis is simply eliminated, it falls out, and we can only recognize its*

presence by the fact that it may occasionally appear as a reversionary form. Thus the Triton, under some circumstances, sinks back to the Perennibranchiate stage, but not in such a way that the individual would first become a Triton and then be transformed back to a Perennibranchiate, but, as I have already made prominent above, simply by no longer reaching the stage of the *Salamandrida* and remaining upon the stage of the *Ichthyodea*. Thus, also, according to my hypothesis, the *Salamandrida* that formerly lived on the shores of the Lake of Mexico, the *Amblystoma Mexicanum*, has sunk back to the stage of the fish-salamander, and the only trace which remains to us of his former height of development is just the inclination, more or less present in every individual, to reach under favorable circumstances the salamander stage again.

But the third and last consequence which my explanation of the facts brings with it lies in the altered part which would be assigned by it to reversion in organic nature. Hitherto atavistic forms have been regarded only as isolated, exceptional cases, interesting, to be sure, in a high degree for our knowledge, but without significance for the course of development of organic nature. Now a real importance would have to be allowed them in this latter regard.

I should assume that reversion may in a twofold manner be a controlling power for the preservation or restoration of a form of life. In one case, as in the Axolotl, where the newer form, standing organically higher, becomes untenable from external causes, and now, as a further development in the other direction does not seem possible, instead of simply dying out, a reversion of the species to the older and less highly organized step follows. But, second, in this manner, *that the older phyletic form is not altogether given up*, while the younger is developed from it, *but that it alternates periodically with the younger*, as we see in the season-dimorphous butterflies. One will hardly urge any objection to it if I regard the alternation of summer and winter form in these as a periodically occurring reversion to the phyletically older form (the winter form).

Though the total reversion of a species, as I assume it for the Axolotl, may be a rarely-occurring case, the *periodically* or *cyclically occurring reversion* surely is not; it certainly plays a considerable part in the origin of various forms of the alternating or cyclical mode of reproduction.

POSTSCRIPT.

It was intimated in the foregoing discussion that the causes from which I derived the reversion of the hypothetical *Amblystoma Mexicanum* to the Axolotl of to-day, did not seem to me to suffice completely for the explanation of the phenomenon. For one thing, they appeared to me of too local a nature, as they could only be applied with certainty to the Axolotl from the lake of the Mexican capital, while also the Paris Axolotl, coming from another part of Mexico, requires an explanation that will apply to him. But, on the other hand, they did not seem to

me cogent enough. For should we even learn at a later time that the Paris Axolotl also comes from a salt lake, which is exposed to winds similar to those of the Lake of Mexico, yet there lies after all in these peculiarities of the lakes only a force which *renders difficult* the metamorphosis of the larva and the gaining of a suitable new dwelling-place on the land. The *impossibility* of attaining such a dwelling, or indeed the *total lack* of it, does not necessarily result from them.

Evidently it would be a much more substantial support for my hypothesis if I succeeded in pointing out forces in the physical relations of the country *which entirely preclude the existence of Amblystoma there.*

SHORT MEMOIRS ON METEOROLOGICAL SUBJECTS.

[Translated by CLEVELAND ABBE.]

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[Bulletin International de l'Observatoire de Paris, 1872, May to July.]

A.

THE DIMINUTION OF THE AQUEOUS VAPOR OF THE ATMOSPHERE WITH INCREASE OF ALTITUDE.

BY DR. JULIUS HANN.

[Translated by Cleveland Abbe from the Journal of the Austrian Meteorological Association, vol. ix, pp. 193–200, July, 1874.]

Mr. Richard Strachey has published, in the Proceedings of the Royal Society of London, March, 1861, a valuable work "On the Distribution of Aqueous Vapor in the Upper Parts of the Atmosphere." In this, he

shows, from the observations of Hooker and his own in the Himalayas, as well as from those that Welsh made in four balloon voyages, that the absolute humidity (or the vapor-tension) diminishes in a much more rapid ratio with the altitude than would be the case in an independent atmosphere of vapor subject to its own pressure only. He then further shows that the existence of an independent vapor atmosphere is excluded by the rate of diminution of temperature with altitude as deduced from all known observations considered together with the vapor-tension observed at the surface of the earth. This latter proposition had already been mathematically demonstrated by Bessel in 1838.* Of course Strachey concludes further that it is not admissible to subtract the vapor-tension from the barometric pressure in order to obtain the pressure of the dry atmosphere.† By means of an estimate based upon Hooker's and Welsh's observations, Strachey finds that the actual pressure of the vapor in the atmosphere is to the tension observed at the earth's surface as 1 to 4. Lamont arrived at the result 1 to 5, nearly agreeing therewith, by making Glaisher's observations the base of his computation.‡

Strachey does not attempt to deduce a formula for the diminution of vapor-pressure with altitude from the vapor-tensions at different altitudes in the atmosphere, as communicated by him; and Lamont has, in the above-cited memoir, expressed his conviction of the non-existence of any regular change of vapor-pressure with altitude. This is, indeed, a necessary consequence of the denial of Dalton's vapor atmosphere; according to this view, the atmosphere of vapor never arrives at that condition of equilibrium which is assumed for it by Dalton's proposition of an independent gaseous atmosphere. At the earth's surface, at higher temperatures, aqueous vapors are developed of greater tensions than would correspond to the possible vapor-tensions that obtain at the lower temperatures in the higher strata of the air. The slow diffusion of aqueous vapor in the air alone prevents its rapid continued condensation in the upper strata. By reason of ascending currents of air, as well as any other cooling of masses of moist air, there occur, now here and now there, condensations of vapor; and under such conditions the existence of a state of equilibrium in the vapor atmosphere cannot be assumed. Were oxygen and nitrogen continually produced, and at lower temperatures again locally condensed in the same proportions as is the aqueous vapor, then a barometric measurement of altitude would be out of the question. We must then *a priori* refrain equally from the deduction of any law permitting one to determine the vapor-pressure at any higher or lower altitude from the vapor-tension observed in any

* Remarks on Barometric Hypsometry, Astron. Nach., Band 16, No. 356.

† We expressly say "atmosphere," since it is of course permissible for physical purposes to subtract the vapor-tension from the barometric pressure in order to obtain the weight or the pressure of the dry air within a definite space.

‡ See this Journal, iii, 291.

atmospheric stratum, and from the deduction of a similar law for the temperature.

But if we examine the vapor-tensions for different altitudes as given by Strachey, we are surprised at the agreement on the one hand between the results of the observations that Welsh made during his balloon voyages and those that Hooker and Strachey made in the Himalayas, and on the other hand at the agreement of the latter among themselves, especially at the greater altitudes. This unexpected fact induced me, following Strachey's steps, to compute the observations of Glaisher's balloon voyages; and since the figures thus obtained agreed very satisfactorily with those of Strachey, I collected also the material known to me relative to observations of humidity at fixed stations at greater mountain altitudes. Thus the following table has resulted. Like Strachey, I have expressed the vapor-tension at a given altitude in a fraction of that simultaneously observed at or near the earth's surface.

Since the altitudes for which observations are at hand seldom agree with the intervals of the table, therefore the required quantities for the nearest tabular interval were computed, by a formula, hereafter given, from the observed values.

Diminution of Vapor-tension with Altitude.

Series.	Value of the quotient $\frac{p}{p_0}$ for each thousand English feet of altitude.														
	1	2	3	4	5	6	7	8	10	12	14	16	18	20	22
Himalaya:															
(*a*)		.82	.78	.68	.61	.63	.56	.52	.42	.35	.29	.25	.20	.16	
(*b*)	[.89]	.85	.82	[.82]	.72	.63	.62	.54	.43	.36	.23	.14	.15		
(*c*)				.69		.57		.50							
Armenia:															
(*a*)		.80			.58			.51	.35			.17			
Teneriffe:															
(*a*)	.83							.30	.28						
Alps:															
(*a*)		.79		.60	.55	.50	.46		.31						
Balloons:															
(*a*)		.88		.77		.58		.45	.35	.30	.19	.18	.16	.12	
(*b*)	.87	.77	.67	.57	.53	.51	.44	.37	.26	.21	.22	.17	.17	.11	.07
(*c*)	.89	.78	.67	.56	.46	.38	.29	.24							
(*d*)	.88	.78	.65	.55		.69	.50	.41	.33	.18					
Means:															
Mountains	[.85]	.81	.80	.66	.61	.58	.55	.47	.36	[.35]	.26	.19	.17	.16	
Balloons	.88	.80	.66	.61	.50	.54	.41	.37	.31	.23	.21	.17	.16	.11	.07
All	.87	.80	.73	.64	.56	.56	.48	.42	.34	.27	.23	.18	.16	.13	.07

(The bracketed numbers have only one-half weight.)

The following are the observations on which are based each individual series of the above table.

Himalaya.—(*a*) Observations by Hooker: (*b*) by Strachey, extracted from the above-cited memoir; (*c*) annual means of observation at Mahabaleshwar and Bombay; at Darjeeling and Goalpara; at Dodabetta and Madras.

Armenia.—Observations by Moritz during his ascent of the Greater Ararat in August, 1850, published in Kupffer's *Correspondance Météorologique, année* 1858. Moritz took hourly observations of nearly all the

meteorological elements for four days at the altitude of 2,316 meters (Sardar-Bonlagh), for ten days at 3,316 meters, and through nearly five days on the summit of the Greater Ararat, 5,125 meters. During the entire time, observations were regularly maintained at Erivan, Alexandropol, Tiflis, Redoute Kalé, and Lenkoran. From these observations, I have deduced the corresponding averages.

Teneriffe.—Observations by Piazzi Smyth at Villa Orotava (374 meters), Guajara (2,715 meters), and Alta Vista (3,264 meters), in July, August, and September, 1856, and simultaneously at Santa Cruz.

The Alps.—Observations at the Theodul Pass, August, 1865 and 1866, in connection with the Swiss system of observations; also the observations of Kämtz on the Rigi and the Faulhorn, referred to Zürich. (Kämtz particularly remarks, in his *Vorlesungen*, that in the dry year 1832 the ratio of the vapor-tensions at Faulhorn and Zürich was 0.43, almost exactly the same as the ratio 0.46 for the damp, cold year 1833.)

Balloon Voyages.—(*a*) Observations by Welsh, computed and communicated by Strachey; (*b*) observations by Glaisher during five trips in summer time; (*c*) three voyages in late summer and fall of 1863; (*d*) three voyages in the winters 1864 and 1865. On the ascension of 1864, January 12, the temperature and humidity at first increased with the elevation, and at a higher altitude first began to regularly diminish.

After a consideration of the figures in the above table, one must confess that the attempt to represent these by any formula is quite as reasonable as the establishment of any ratio for the diminution of temperature with altitude. The agreement between observations on mountains and in the free atmosphere in balloons is much better for the humidity than for the temperature. Only the Himalaya observations show for small altitudes a materially greater quantity of vapor on the mountains than in the free atmosphere; at great altitudes, there is scarcely any difference. Had the vapor atmosphere of the earth attained to a condition of equilibrium, and subject to its own pressure only, we could in a simple manner compute the pressure corresponding to a given altitude, since for every such gaseous atmosphere the equation

$$p = p_0 e^{-\frac{h}{C\,\phi(t)\,\phi(g)}}$$

must obtain. Here p and p_0 represent the pressures at the altitude h and at the earth's surface, measured by the height of the mercurial column supported by these pressures; e is the base of the natural logarithms; C is a constant, and equal to the product of 0.760 into the ratio between the density of mercury and that of the gas under a normal pressure of 0.76 meter at a temperature of 0° C. and with the intensity of gravity as at the sea-level at 45° latitude. This constant corresponds to the altitude of a column of gas of uniform density and at the uniform temperature of 0° C., which exerts the same pressure as a mercurial column of 0.76 altitude. For another temperature of the gaseous column, and for another value of the force of gravity, and one diminishing with the

altitude, the above altitude must be different; $\varphi(t)$ and $\varphi(g)$ indicate the correctional factors. For dry air, free from carbonic acid gas, C is 7,992 meters, and since the density of aqueous vapor may be assumed constant at 0.623 for ordinary atmospheric temperatures, therefore for an atmosphere of aqueous vapor $C = 12{,}829$ meters. We therefore have the following formula for the computation of the pressure at any altitude within an atmosphere of aqueous vapor, and omitting the small corrections,

$$\text{nat log } p = \text{nat log } p_0 - \frac{h}{12829};$$

or, multiplying by the modulus of the Briggs logarithms,

$$\log p = \log p_0 - \frac{h}{29539}.$$

This formula can be used at once to compare the observed diminution of vapor-tension with that which must obtain in an independent atmosphere of aqueous vapor. Up to an altitude of 20,000 English feet, or 6,096 meters, the correction $\varphi(g)$ can be neglected, and the introduction of $\varphi(t) = 1 + at$ would have the effect of still further delaying the diminution of tension up to about 12,000 feet.

Theoretical and Observed Diminutions of Vapor-tension.

	Altitudes in thousands of English feet.					
	0	4	8	12	16	20
p computed	1.00	0.91	0.83	0.75	0.68	0.62
p observed	1.00	0.64	0.42	0.27	0.18	0.13

Whence the vapor-tension actually does diminish with the altitude much more rapidly than would be the case if an independent gaseous atmosphere existed.

As before remarked, Bessel had already, through a roundabout and involved computation, proven that the slow diminution of vapor-tension with the altitude, as is required in Dalton's vapor atmosphere, cannot possibly be reconciled with the known diminution of temperature, for aqueous vapor has a definite maximum of elastic force for each temperature. Our above-written formula must therefore also satisfy the conditions

$$p = p_0\, 10^{\frac{-h}{29539}} \text{ and } p \text{ equal or less than } 4.525 \times 10^{\frac{7.4475\,t}{234.69+t}}.$$

The last member on the right is the formula given by Magnus for the maximum tension of aqueous vapor for a given temperature t. Hence follows

$$\log p_0 = \text{or} < 0.65562 + \frac{7.4475\,t_0}{234.69+t_0} + \frac{h}{29539}.$$

For an average temperature diminution of 0°.5 C. for each 100 meters, the mean annual temperature will be $-5°$ C. at an altitude of 3,000 meters above Vienna ($-6°.6$ is observed at the Theodul Pass, altitude 3,330 meters). If we substitute these values for h and t_h, we find

$$\log p_0 = \text{or} < 0.48342 \text{ and } p_0 = \text{or} < 3.9 \text{ millimeters.}$$

Therefore, even were the air, at 3,200 meters altitude, saturated with vapor, the vapor-tension in Vienna would, at the highest, be only 3.9^{mm}; in fact, however, it is observed to be 6.9^{mm}. In order to make this tension possible, the temperature at 3,000 meters altitude must be $+2°.4$ C., and therefore the rate of decrease of temperature would amount to only 0°.25 C. for each 100 meters.

If now we seek to represent the observed diminution of vapor-tension by means of an empirical formala, we can either choose a simple expression of the form

$$p = p_0 (1 + a h + b h^2),$$

or examine whether the observed values proceed in a geometrical progression, in which case the value of C is to be determined, which must be much smaller than the above given theoretical value.

I first deduced, according to the method of least squares, from the mean of the series Himalaya (a) and (b) and Balloon Voyages (a) and (b), the formula

$$p = p_0 (1 - 0.078 h + 0.00164 h^2),$$

where h is given in units of 1,000 English feet each. If we use also the observation of Glaisher that for $h = 28{,}000$ feet p is nearly equal to zero, we find

$p = p_0 (1 - 0.075 h + 0.00146 h^2)$, h in units of 1,000 English feet;

or

$p = p_0 (1 - 0.246 h + 0.01569 h^2)$, h in units of 1,000 meters.

These formulæ of interpolation represent, with almost perfect accuracy, the observations on which they are based, but are inapplicable to altitudes above 7,800 meters, since for higher altitudes they give increasing values of p (for $h = 26{,}000$ feet, the second formula gives $p = 0.04$). But this does not prevent their application to all cases that actually occur.

In order to express the definitive mean values of our table, the quantities $\frac{p}{p_0}$, by a geometrical progression, I have pursued the following method: The general formula is, for our case, converted into

$$\log \left[\frac{p}{p_0}\right] = -\frac{h}{C}; \text{ whence } C = -\frac{h}{\log (p : p_0)}.$$

I now computed the values of C for 14 of the intervals of the table (excluding the last [22], because for this the $\frac{p}{p_0}$ depends upon too few

observations); for the first intervals, from 1 to 8,000 feet, I united each three into one mean value, and thus obtained the following:

Altitudes in English feet.	C in English feet.	Altitudes in English feet.	C in English feet.
2,000	19,707	12,000	21,103
4,000	20,815	14,000	21,935
6,000	21,883	16,000	21,485
8,000	21,515	18,000	22,616
10,000	21,344	20,000	22,576

The reduction of the observed values of the vapor-tension to the nearest intervals occurring in the table was made by means of interpolation after the values of C had been computed from every observation. These numbers show an increase of the value of C with the altitude. The method of least squares now gives us the expression

$$C = 20251 + 0.11334\,h \text{ in English feet,}$$

or

$$C = 6172 + 0.11334\,h \text{ in meters,}$$

where h is to be expressed in units of either English feet or meters respectively. The mean value of C as computed by this formula is 6,517 meters. Since small changes in C have but slight influence upon the value of $\frac{p}{p_0}$, we can also try the effect of considering C as a constant equal to 6,517 meters.

The following table shows that in fact this is perfectly allowable:

Altitudes (in thousands of English feet)	1	4	8	12	16	20	24	28
Observed p	0.87	.64	.42	.27	.18	.13	—	—
Computed p (C increasing)	0.88	.64	.42	.28	.19	.13	.09	.06
Computed p (C constant)	0.90	.65	.42	.27	.18	.12	.08	.05

Whence it appears that the observed values of vapor-tension at different altitudes are represented with almost perfect accuracy by the formula

$$p = p_0\, 10^{\frac{-h}{6517}} = p_0\, e^{\frac{-h}{2830}}$$

We must for the present leave undecided the question whether the constant 6517 varies with the temperature, as may be suspected from the slower diminution of the vapor-tension among the Himalayas, since the observations are too few to determine such a coefficient with any security.

From the expression just deduced empirically for the diminution of vapor-tension with altitude, as compared with the formula previously given, which would obtain for an independent atmosphere of aqueous vapor, we conclude that the ratio of the weight of the aqueous vapor actually present in the atmosphere, as compared with the weight resulting from the Dalton hypothesis, is as the ratio of the values of C in both formulæ, or as 2830 to 12829, or as 0.22 to 1. *Whence, the weight of the vapor present in the whole atmosphere above the place of observation, according to Dalton's hypothesis, is 4.5 times greater than it is in reality.*

One can persuade himself of the correctness of this conclusion by the following computation. The weight (in kilograms) of the aqueous vapor having a tension p (in millimeters) in one cubic meter is found by the well-known formula

$$q = 0.623 \frac{S_0}{1 + \alpha t} \cdot \frac{p}{760} = \frac{0.001058}{1 + \alpha t} p,$$

where S_0 is the specific gravity of air at temperature 0° C. Hence the weight of aqueous vapor contained in a stratum of air of differential thickness dh and horizontal area unity is

$$dq = \frac{0.0010582}{1 + \alpha t} \cdot p_0 10^{\frac{-h}{6517}} dh.$$

The integration of this equation gives a formula for the total weight of the aqueous vapor contained in the atmosphere up to any definite height. The temperature t is, strictly speaking, also dependent on the altitude; but we will, in accordance with all experience, put

$$t = \frac{t_0 + t_h}{2} = t',$$

and thus find

$$Q = \frac{0.0010582}{1 + \alpha t'} p_0 C \log e \left(1 - 10^{\frac{-h}{6517}}\right),$$

or

$$Q = \frac{0.0010582}{1 + \alpha t'} p_0 \times 2830 \left(1 - 10^{\frac{-h}{6517}}\right)$$

For large values of h, therefore, by extending the integral to the limits of the atmosphere, the negative member of this expression disappears, and it is now quite clear that the actual weight of the aqueous vapor in the atmosphere is to that resulting from Dalton's hypothesis as 2830 to 12829, or as 0.22 to 1.

For example, the mean vapor-tension at Vienna in July is 11 millimeters, the temperature 20°.3 C.; at the altitude of 8,000 meters, the probable temperature is about −19°.7 C.; the mean temperature of the whole atmosphere of aqueous vapor is therefore nearly 0° C. The formula gives the total weight of aqueous vapor = 33 kilograms, corresponding to a pressure of $\frac{33}{10332} = 0.0032$ atmosphere, or a mercurial column of 2.4 millimeters. If, therefore, the aqueous vapor contained in July in the atmosphere above Vienna could expand according to Dalton's law, the vapor-tension at the earth's surface would sink from 11 millimeters to 2.4 millimeters.

[NOTE.—The following equation resulting by integration from our previously given formula of interpolation:

$$Q = \frac{1.0582}{(1 + \alpha t)} h\, p_0 (1 - 0.123\, h + 0.00523\, h^2),$$

where the unit of h is a thousand meters, gives $Q = 32.6$ kilograms, or 2.3 millimeters on the mercurial barometer, for $h = 8{,}000$ meters.]

The formula for Q further teaches us that one-half of the whole quantity of aqueous vapor is contained in the strata of air below the altitude of 1,962 meters, or 6,043 Paris feet, and that only one-tenth of the whole aqueous vapor in the atmosphere is above the altitude of 6,500 meters, or 20,000 Paris feet. Strachey is therefore right in saying that the mountain-ranges, however slight their altitudes are in respect to the dimensions of the whole globe, yet must be of great influence in reference to the aqueous meteors. A mountain-chain of only 6,000 feet altitude forms a dividing barrier for one-half of the vapor in the atmosphere; the Himalayas, with an altitude of about 15,000 feet, or 4,600 meters, cuts off eight-tenths.

In conclusion, I would expressly remark that the formula deduced for the diminution of vapor-tension with altitude can only be applied with security to the computation of mean ratios. It can also be practically applied in barometric hypsometry, since all the more recent hypsometric tables take into consideration the aqueous vapor of the air, but frequently the vapor-tension is known for only one of the two stations whose relative altitude is to be determined. The following example shows that for this purpose the accuracy of the formula is quite sufficient. Bauernfeind observed the psychrometer twenty-one times daily during five days at five stations on the Greater Miesing, whose relative altitudes were determined by direct leveling. (See *Beob. und Unters. über die Genauigkeit barometrischer Höhenmessungen*, München, 1862, p. 132.) The following small table contains the means of these observations, and beneath them are given the values computed by our formula for the other stations from the observations at station I:

Stations	I.	II.	III.	IV.	V.
Altitude in meters	816	1086	1356	1619	1884
p observed, Paris lines..	5.16	4.30	4.02	3.79	3.54
p computed from I.....	—	4.69	4.26	3.88	3.54

We shall be perfectly satisfied with the agreement between observation and computation if we reflect that Baurnfeind's observations were not used in the deduction of our formula, because they appeared to us to relate to far too slight an altitude.

[NOTE.—The mean vapor-tension in Klagenfurt is 7.1 millimeters. Hence, for the station Hoch-Obir, lying 1,603 meters higher, is computed a mean vapor-tension of 4.03 millimeters. Prettner (*Klima von Kärnthen*, p. 163) gives for Hoch-Obir a relative humidity of 82 per cent. and a mean temperature of 0°.85 C., according to psychrometer observations, for one year, 1852. To these figures there corresponds a vapor-tension of 4.02 millimeters; therefore, exactly equal to the computed value.]

Notwithstanding the agreement between observation and computation in these and other cases, no deeper theoretical meaning should be attributed to our formula. It is perhaps only a more exact expression for the opinion expressed by Strachey, that the average degree of saturation of

the air remains quite uniform in different altitudes. Therefore, the vapor-tension depends only on the diminution of temperature. If this latter proceeds in an arithmetical progression, there follows, of course, for the diminution of vapor-tension a geometric progression. Only the demonstration may be new, that we can also, with so great accuracy, from observations at one altitude, compute also the mean vapor-tension at another altitude.

B.

ON THE INFLUENCE OF RAIN UPON THE BAROMETER, AND UPON THE FORMATION OF PRECIPITATION IN GENERAL.

By Dr. J. Hann.

[Translated by Cleveland Abbe from the Journal of the Austrian Meteorological Association, 1874, pp. 289 *et seq.*]

A more accurate knowledge of the influence which the condensation of the aqueous vapor in the atmosphere exerts upon the disturbances of its equilibrium and upon the changes of atmospheric pressure is at present of special importance, since, in the theory of storms, we have to a certain degree returned to the views of Espy.[1] This may be our excuse that we once more return to this subject after having, in a previous volume of our periodical,[2] given place to a discussion upon this subject. At that time I had to refer to the contradiction that appeared to exist between the theory and the computations of Espy, Kronig, and Reye and the observed facts. According to Espy and Reye, the condensation of vapor into cloud and rain produces a considerable fall in pressure under the place where the rain falls. But every careful observer knows, on the other hand, that the tendency of rainfall appears to be rather to increase the pressure. The barometer rises during the rain, and after the rain stands higher than before. If the rain had the effect computed by Reye, to diminish the pressure, or even a much less effect, then would the reverse take place. It, indeed, rains generally during low pressures; but the lowest barometer precedes the rain;—if it were a consequence of the rain, it would occur during or after the rainfall. Reye has had the kindness to go into the discussion of this point, and thereby has in great part removed the apparent contradiction between computation and observation.[3] He allows that, in the case where the precipitation is produced by the inflow of colder air or by radiation or conduction of heat, and where the latent heat of condensation is thus neutralized, the pressure can rise during the rain; that equally, in the case where new masses of air steadily flow toward the place of precipitation (the rainfalls of a moist current of air blowing over a mountain), the formation of a barometric minimum will be hindered. But if we now consider the remaining causes of the formation of precipitation, we

find all are included in the preceding except the one case of a current freely rising in a quiet atmosphere, and which, cooling by expansion, precipitates its aqueous vapor. To this class especially belong many of our summer rains, but especially the tropical rains.

But even our summer rains also behave, with respect to atmospheric pressure, precisely as we have above described; and with respect to the tropical rains, we read in general that they exert scarcely any influence upon the barometer, not even disturbing the regular diurnal oscillation. But upon this point only a computation of the observations which are the numerical presentation of the influence of rain upon the barometer can decide. Observations in our climate are not convenient to such a computation, since we cannot properly eliminate the precipitation due to the inflow of cold currents. Hence, I have chosen Batavia, a place in the tropics near the equator, for which I have before me the three years of hourly observations of pressure and of rainfall published by Bergsma.[4]

Before I proceed to communicate the results of my computations, I must state that I cannot participate in the view expressed by Reye (vol. 8, p. 180), who there says: "It can, indeed, occur that upon mountain-tops, where the vapor condenses to clouds, the pressure may also diminish; but, for all that, the barometer need not fall at the place, 80 miles away, where the clouds discharge their rain." The clouds are not to be considered as magazines, in which the previously formed rain is carried along to be discharged anywhere. There where it rains is the location of an increased precipitation, and the pressure must sink deeper there than where clouds only form without developing into rain.

The hourly observations at Batavia show at once, even by a cursory review, that in fact, as was expected, even the heaviest rains scarcely disturbed the diurnal change in pressure, and this stands forth with greatest clearness in the averages. I took for computing the corresponding pressures only the rainfalls which gave at least 10 millimeters in an hour. The pressures for one and two hours preceding and following the rainfall (often of many hours' duration), as well as the pressures during the first, second, and third hours of rain, were extracted, were separately reduced to the daily means by means of the mean diurnal variation, and then united in a general average. I thus obtained the following numbers, to which I have also added the mean rainfall for each hour, so that one can perceive how intense these rains are. For comparison, I add that in Vienna, on the average, an entire rainy day in summer affords 5.0 millimeters of water, but in winter 2.7. The mean of six of the heaviest rains during one hour from 1853 to 1871 is 20.5 millimeters.

Influence of Rain on Pressure in Batavia.

I.—RAINS BETWEEN 9 A. M. AND 9 P. M.[5]

Number of cases.	Year.	Barometer 750 millimeters +							Quantity of rain—				
		Before—		During—			After—		During—				
		2h.	1h.	1h.	2h.	3h.	1h.	2h.	1h.	2h.	3h.	4h.	5h.
		mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
22	1866	8.87	9.02	9.30	9.32	9.32	9.19	9.08	16.4	13.6	8.2	10.6	4.3
11	1867	8.31	8.47	8.67	8.87	8.77	8.75	8.80	24.5	7.6	0.6	0.7	0.3
8	1868	8.51	8.72	8.82	8.88	8.70	8.65	8.56	13.4	9.0	2.0	1.8	0.6
41	Mean	8.65	8.81	9.04	9.11	9.04	8.96	8.92	17.9	11.1	5.2	6.5	4.3

II.—RAINS BETWEEN 9 P. M. AND 9 A. M.

8	1866	8.60	8.70	8.86	9.00	9.00	8.72	8.85	10.3	2.6	5.4	5.6	5.0
16	1867	9.26	9.29	9.41	9.48	9.58	9.51	9.53	11.2	21.5	9.6	4.7	2.4
8	1868	9.66	9.79	9.92	9.75	9.85	9.85	9.71	15.9	6.1	3.7	0.9	0.2
32	Mean	9.19	9.26	9.40	9.43	9.50	9.40	9.43	12.2	12.3	7.6	4.9	3.6

Here also, during the rainfall, the pressure rises, and after the rain stands higher than before. If we start with the pressure before the beginning of the rain, and compute the hourly changes, we obtain the following variations of pressure:

	Before—		During—			After—	
	2h.	1h.[6]	1h.	2h.	3h.	1h.	2h.
Day-time	758.65	+ 0.16	+ 0.23	+ 0.07	− 0.07	− 0.08	− 0.04
Night-time	59.19	+ 0.07	+ 0.14	+ 0.03	+ 0.07	− 0.10	+ 0.03
Mean	58.92	+ 0.12	+ 0.18	+ 0.05	0.00	− 0.09	− 0.01

The pressure rises at the beginning and during the first hours of the rainfall by about 0.35; it falls within the two hours following the rain by 0.10, and therefore after the rain it always stands 0.25 higher than before. The changes at night-time are somewhat smaller than during the day-time. I have also combined in one average thirteen cases of the heaviest rains (over 20 millimeters an hour); they give the following changes:

	Before rain.		During rain.		After rain.	
	2h.	1h.	1h.	2h.	1h.	2h.
Heaviest rains	758.58	+ 0.14	+ 0.17	+ 0.12	− 0.16	− 0.05

The barometer stands 0.22 higher after the rain than before it.

If we compare the mean pressure before, during, and after the rain with the annual mean pressure, we obtain the deviations:

Before.	During.	After.
− 0.05	+ 0.28	+ 0.20

Since the mean daily range of the barometer in Batavia amounts to 2.7 millimeters, it follows that the influence of the rain is insignificant in comparison therewith, and we have a plain confirmation of the statement that in the tropics the rain does not disturb the diurnal oscillation of the barometer.

I make the following extract from a letter of Blanford, to whom I communicated the result of my computation of the Batavia observations with the inquiry as to whether he could perhaps refer to opposing observations in India: "The result you have obtained from the Batavia observations, viz, that the barometer is lower before rain than during or after it, is completely in accordance with my own observations at Calcutta."

I consider the slight increase of pressure here demonstrated during and after the rain not as a primary effect of condensation of vapor, which therefore would be operating in a contrary direction to that assumed by Espy and Reye, but only as a secondary effect due to the cooling of the lower strata by the rain-drops descending from higher, colder strata and by evaporation. Perhaps, also, the impact of the falling water and the air dragged down with it contributes somewhat to the initial rapid rise of pressure, but a reason to be given later can also cause the barometer to rise somewhat before the rain.

We believe ourselves now to be justified in the conclusion that the condensation of aqueous vapor in the atmosphere has no appreciable influence on the change of atmospheric pressure. The low barometers of the storm centers can therefore not be explained by the precipitations, although these latter may probably be an occasion for their development, to which point we will subsequently return.

We will next consider the solution of the contradiction that exists between the theory which assumes a considerable fall of pressure under a precipitation and the above-given results of observation, which reveal nothing of the kind.

The computation of Reye on the magnitude of the influence on the pressure of the condensation of a given quantity of atmospheric aqueous vapor is based upon the following train of thought: If the vapor in a mass of moist air is condensed, the expansive force of the air, and therewith its volume, is at first diminished, but the air is at once so strongly warmed, and thus again expanded, by the liberated latent heat of the condensed vapor, that the original contraction is many times exceeded. Reye computes that the expansion at 30° C. is somewhat more than five times the initial contraction; at − 10° C. it is somewhat more than six

times as great. Imagine a vertical column of one square meter section isolated from the atmosphere, and assume that a kilogram of water falls therein as rain, so that the rainfall is 1 millimeter. The air thereupon expands considerably, and at a temperature of 10° C. at the place of condensation 7.3 kilograms of air, on account of this expansion, either are pressed to one side or are pressed upward, where they can flow to one side. The weight of the column of air, which on the average amounts to 10,336 kilograms, or one atmosphere, has therefore diminished by 8.3 kilograms, including the condensed aqueous vapor. The average barometric pressure must therefore have diminished by $8.3 \div 10336 \times 760 = 0.61^{mm}$: therefore $\frac{3}{5}$ of the depth of rainfall. This makes the fall in the barometer about 7 lines, or nearly 16 millimeters, for an inch of rain. Of course this computation gives only the maximum change in the barometer, which in reality is by far not attained, for the outpressed air cannot immediately flow away, and, moreover, is at the earth's surface in great part replaced by colder air flowing from either side ("Die Wirbelstürme," page 215, and Pogg. Ann., 1865, vol. cxxv). Kronig has in a similar way endeavored to prove, in opposition to Mohr, that the expansion overbalances the contraction (Pogg. Ann., 1864, cxxiii).

By both physicists the computation is conducted under conditions that do not occur in nature. Vapor condenses, not spontaneously, but only when the air is cooled; and this cooling must be greater than the liberated latent heat, or else it certainly cannot cause any precipitation. There remains, therefore, no surplus heat that can expand the air to more than its previous volume. The latent heat of the vapor has simply the effect of diminishing the cooling; that is to say, it replaces a portion of the heat that is lost. But a cooling must take place, and therefore, if we, in the above-imagined column of air, would bring a kilogram of vapor to condensation, we must take away the whole of its latent heat, and also deprive the air of so much heat as corresponds to the contemplated reduction of the vapor-tension. The mass of air will therefore contract; consequently new air will flow in from above or from the sides, and the barometer at the base of the column of air must rise. This is the process which takes place in nature during the precipitations that occur by reason of the inflow of a colder current of air, or by reason of cooling in consequence of radiation and conduction.

In the precipitations of ascending currents, heat is consumed in the expansion of the air, and any accompanying condensation of vapor and liberation of latent heat has the effect of diminishing the cooling of the air.

When we overlook this circumstance, we come, as Wettstein did, to the question, Whence comes the heat rendered latent by the condensation of vapor? and to the opinion that a heavy precipitation is impossible in the atmosphere if this heat is not immediately converted into electricity[7] (*Die Beziehung der Elektricität zum Gewitter, Vierteljahrs-*

schrift der naturforschenden Gesellschaft in Zürich, 14. *Jahrg.*, 1869). "The thunder-storm begins with a precipitation of vapor in consequence of the cooling of the air; this precipitation is, however, accompanied by a development of heat, and this heat developed by the condensation of vapor constitutes the chief difficulty in the explanation of thunder-storms." Wettstein now computes for a few cases the quantity of heat set free by the condensation of vapor, and investigates whether the cooling processes that occur in nature suffice to remove this quantity of heat and to render possible the condensation of vapor. We will delay somewhat over this chapter of the interesting work of Wettstein, because the citation of his computations and the proof of the errors that have slipped in will best lead to the recognition of the important part that the ascending movement of the air must play in all heavier processes of precipitation.

Wettstein first considers the cooling of ascending moist air. He computes the diminution of temperature according to a well-known formula of the mechanical theory of heat for the case where no condensation takes place. For an ascent of 1,000 meters, there results a cooling of 10° C.; for 2,000 meters, 20°; for 3,000 meters 29°; for 4,000 meters, 38°; for 5,000 meters, 47°. If, now, the air was originally 25° C. warm, and saturated with vapor, then, by its ascent, vapor will be condensed; as, for instance, for 1,000 meters ascent, $22.83 - 12.74 = 10.09$ grams per cubic meter; the latent heat thereby liberated is $10.09 \times 0.590 = 5.96$ units of heat, which suffices to raise the temperature of the air and the condensed water by more than 18°.5 C. Since the cooling due to expansion amounts to only 10° C., therefore Wettstein concludes that precipitation is impossible. In a similar manner, he finds for an ascent of 2,000 meters an excess of nearly 10° C. of warmth, for 3,000 meters nearly 6 C., and for 4,000 meters, 0°.7 C.

For a current of air rising up to 5,000 meters, the cooling is 47°.2, and the warming 41°.4; therefore the resultant cooling 5°.8; from these figures, it follows, says Wettstein, that the lowering of the temperature of the air, in consequence of its expansion, will, up to heights of more than 4,000 meters, be neutralized by the heating due to the condensation of vapor, and that the ascent of warm moist air can be accompanied by precipitation, first at very great altitudes, between 4,000 meters and 5,000 meters.

The vicious reasoning here presented consists in this, that an amount of precipitation is introduced in the computation that cannot possibly occur in nature. The air, by an ascent of 1,000 meters, will, indeed, in consequence of vapor, cool by less than 10° C., but cool it will somewhat, and consequently some precipitation must occur. We shall subsequently see that in the supposed case, air saturated at 25° C., the cooling amounts to 0°.4 for each hundred meters of ascent, and therefore for a thousand meters amounts to 4°. This would give for each cubic meter a precipitation of 4.66 grams. If the ascending current has the very moderate

velocity of 2 meters per second, the precipitation on a base of one square meter in one hour would amount to 33.6 kilograms, corresponding to a depth of rainfall of 33.6 millimeters. This, therefore, would give a rainfall of greater intensity than has ever yet been observed at Vienna. It is, therefore, certainly not necessary to take refuge in the assumption of a conversion of heat into electricity in order to explain the heaviest rains of thunder-storms by the ascending currents of moist air.

Wettstein then considers the mixing of warm and colder air. He assumes that a cubic meter of air saturated at 25° is mixed with a cubic meter of air also saturated at 0°; there result 2 cubic meters having, if we at first neglect the latent heat of condensation, a mean temperature of 12°.5. These two cubic meters contain $22.83 + 4.87 = 27.70$ grams of aqueous vapor[8]; but at 12°.5 C. only 21.92 grams can be contained as vapor in 2 cubic meters, therefore 5.78 grams will be condensed. This condensation liberates a quantity of heat which is sufficient to warm the air by 5°.6, so that its temperature rises to 18°.1.

At this temperature, however, 2 cubic meters of air can contain 30.68 grams of vapor, or more than is contained in the two masses of air together. It follows, thence, that precipitation can also not be produced by mixture.

Here again we have to do with the same vicious reasoning as in the preceding case.[9] In consequence of the warming of the air due to the condensation of vapor, 5.78 grams of the latter will not be condensed, but less. By trial we easily find that the mixing will bring about a temperature of somewhat less than 14°.9 C.; 2.44 grams of vapor will condense, whose latent heat suffices to raise the temperature of the air by not quite 2°.4 C. above that which would have been given by a mixture of dry air. The case here assumed of the combination of masses of air saturated at 25° and at 0° certainly occurs very seldom in nature; even differences of 10° in the temperatures of currents of air are not frequent. We assume, however, now the very favorable case of a mixture of a saturated stratum of air 1,000 meters deep with a saturated current 15° colder throughout its entire extent. In its lower portions, the warm air has a temperature of 25°, its upper portion 20°; consequently the cold current has, respectively, 10° and 5°. Since each cubic meter of warm and of cold air mutually interpenetrate each other, there will be condensed from every pair of cubic meters in the lowest strata about 1.0, but in the highest strata 0.8; on the average, therefore 0.9 gram of vapor. This gives for the entire depth of the stratum of air 0.45 kilogram of water per square meter, therefore a depth of rainfall of 0.45 millimeter. The mixed stratum has now attained a mean temperature of about 16°, but since the cold current continually supplies new masses of air averaging 7°.5 C., the precipitation continues with diminishing intensity until the temperature has sunk to 10° at the bottom, but at the top to 5°. The maximum quantity of water that can altogether fall for a cooling of 7°.5 would be about 11.9 kilograms per square meter,

or a rainfall of 11.9 millimeters; but since at least 4.05 kilograms of air at 10 C. must be mixed with each kilogram at 25° in order to lower the temperature to nearly 10°, and to absorb the latent heat of the 13.47 grams of vapor that will thereby be condensed, therefore it is improbable that this maximum will ever be attained. This quantity of water will [most probably] be distributed over a large extent of surface.

By the flowing of warm and cold currents over each other, notwithstanding the slight depth of the stratum in which the mixture of the air and condensation take place, there can fall, in the course of time, a considerable amount of water upon a unit of surface, but the density of the precipitation in this case will be less than in the foregoing.

From this exposition it appears to me to follow that the mixture of masses of moist air of different temperatures cannot produce any very intense or heavy precipitation, and that the ordinary presentation of Hutton's rain theory leads to an overestimate of the quantity of precipitation due to this source. The frequent occurrence of heavy precipitation on the occasions of inflow of colder currents of air we explain to ourselves by the co-operation of an ascending current in connection therewith.

The cooling of the air at the earth's surface [itself cooled by radiation] can cause only local precipitation confined to a thin stratum of air. In this manner originates the ground fog, which is with us most frequent in the early spring, and also the ground fog of the Polar Regions, often extraordinarily dense, but reaching only to a slight altitude, of which Middendorf, in his volume of journeys in Siberia, has given graphic descriptions. The radiation of heat from the moist air itself, even if we, with Tyndall, ascribe to it a great power of radiation, can certainly only produce a relatively thin covering of clouds, whose formation must in great part or entirely hinder a further loss of heat from the lower strata.

The ascending movement of moist air must therefore be considered as the most fruitful source of precipitation, a result which was long since ascertained by observations, but is in the preceding now also deductively established. We will in our next article turn to the consideration of the causes of the ascending movement of the air, concerning which subject in recent times exhaustive works have been published, which have not yet received corresponding notice in this journal.

NOTES.

No. 1. Zeitschrift, vol. ix, page 245.

No. 2. Zeitschrift, vol. viii, pages 102 and 177.

No. 3. Zeitschrift, vol. viii, page 177.

No. 4. We take this occasion to emphasize the importance of the publication of hourly observations of all the meteorological elements for at least one normal station in each country of average magnitude. That which at the present seems superfluous

will certainly in the future be felt as a disastrous neglect, which in most cases can never be made up.

No. 5. This limitation was selected with reference to the diurnal turning-points of barometric pressure; it also agrees well with the time during which the ascending current of air is active. Cases of rain continuing more than three hours are so rare that no averages are to be taken.

No. 6. Properly this is the hour between which and the following that rainfall is measured which has been entered under the first hour of rain.

No. 7. Even J. Müller, in his Cosmical Physics, has taken no notice of the necessary cooling, and, moreover, has introduced into the computation the latent heat of a kilogram instead of a gram of vapor (3d ed., page 678).

No. 8. Wettstein has used somewhat different numbers for the maximum weight of aqueous vapor in a cubic meter of saturated air. I know not whence they come; they are neither the ordinary numbers nor those given in Zeuner's Grundzüge, table I, page 8. For the sake of uniformity with subsequent computations, I have throughout substituted the values given by the ordinary formula

$$q = 0.623 \frac{S_0}{1 + at} \cdot \frac{e}{760}.$$

No. 9. Espy, also, in his Philosophy of Storms, guided by similar computations, has, like Wettstein, rejected Hutton's theory of rain.

C.

In reply to some remarks by Captain Hoffmeyer, Dr. Hann publishes the following additional note:

ATMOSPHERIC PRESSURE AND RAINFALL.

[Translated by Cleveland Abbe from the Journal of the Austrian Meteorological Association, x, p. 11, 1875, January 1.]

Captain Hoffmeyer criticises a partially unjustifiable generalization from the result of observations, which in strictness only holds good for localities on the north side of the Alps. To this note, Captain Hoffmeyer adds a series of remarks and conclusions that are the more valuable in the theory of storms, inasmuch as they rest upon the unprejudiced daily study of facts, which at present are scarcely found collected together and collated at any other place in such abundance as at the Meteorological Institute in Copenhagen.

I can almost perfectly accede to the views of Captain Hoffmeyer, and this will be evident to every reader of my essay published in vol. ix of this journal; but my objection to the theory of Espy and Reye, that the ascending current of air is the only or the chief cause of the barometric minimum at the storm center, seems to me not thereby disturbed. According to my way of thinking, the position of the question is at present as follows: Observations show that the heaviest rains in the tropics have so slight an influence on the atmospheric pressure that they are unable in the least to disturb the regular diurnal variation of pressure. Now, it seems to me illogical to assume that the same cause can under quite analogous conditions be accompanied by opposite consequences.

The objection that the tropical rains (and the summer rains) are of much more local nature than the winter rains of temperate and arctic latitudes I can only designate as a make-shift, for the great intensity of the tropical (and summer) rains must make up for their slight extent at least so far that a tendency to a fall of the barometer must be evident in the observations. The demonstration that the tropical rains always have a less extent than the precipitations accompanying the storms of higher latitudes must at any rate be first produced,* and after that the proof will still have to be given showing why the heat liberated by the ten and twenty times heavier equatorial rains cannot cause an ascending current intense enough to cause a depression of even 2 or 3 millimeters in the barometer at the earth's surface, while our winter rains are accompanied by depressions of 30 or 40 millimeters.

We have, on the other hand, no observations that would, beyond doubt, prove that the formation of clouds and rain is alone able to sensibly

*I am persuaded that in many tropical countries, especially in the equatorial zone itself, during the rainy period, precipitation occurs simultaneously over a region which is at best as large as that which corresponds to the last half of our own revolving storms. It is a rather widespread error that the rainfall in the tropics always occurs in the form of local thunder-storms. There occur equally uniform and constant rains there, as is the case with our own general rains. On this point, I refer only to the Reports of Frantzius on the Atlantic Coast of Central America ("Zeitschrift für Erdkunde," 1868), of Humboldt and of Bates ("Der Naturforscher am Amazonenstrom") on the region of the Amazon; *e. g.*, Bates says: "From the 14th to 18th January the weather was bad; it rained sometimes twelve hours in succession, not heavy, indeed, but steadily drizzling, as in England." As soon as we approach the equator within 3° of latitude, we seldom find opportunity to observe sun and stars. The missionary in San Antonio de Javita assures us, says Humboldt, that he has often seen it rain here four or five months without cessation. These are certainly no local rains, for these remarks refer to the uniform lowland of the Middle Amazon and to the Rio Negro. Even in Vienna it is seldom that rains continue twenty-four hours or more. According to the five years of registers of a rain-autograph, there occur on the average in a year only 4.3 precipitations that last over twenty-four hours. (See Hann, Met. Windrosen für Wien, Sitzb. K. Akad., 1867.)

By reason of the great attention that travelers have given to the regular daily changes of the barometer, it would be highly remarkable if any connection between the rain and the barometric depression had escaped them in a climate where there are no irregular changes of pressure in consequence of changes of wind-direction. And yet one finds no note as to the presence of any such relation between rain and pressure—the remarks express themselves directly against such connection. I will here quote only one passage from Herschel's Meteorology, page 163: "Colonel Sykes remarks (Phil. Trans., 1850) that, among many thousand observations taken personally by himself on the plateau of the Deccan (1825–1830), there was not a solitary instance in which the barometer was not higher at 9 or 10 a. m. than at sunrise, and lower at 4 or 5 p. m. than at 9 or 10 a. m., whatever the state of the weather might be." Humboldt also observes (tome 1, p. 308): "This regularity is such that, in the daytime especially, we may infer the hour from the height of the column of mercury without being in error on an average more than 15 or 17 minutes. In the torrid zone of the new continent I have found the regularity of this ebb and flow of the aërial ocean undisturbed either by storm, tempest, rain, or earthquake, both on the coasts and at elevations of nearly 13,000 feet above the level of the sea."

diminish the atmospheric pressure. But when now we see that the pressure in the center of a whirl sinks very low so soon as these rains fall in consequence of a rotatory motion of the air, must we then not conclude, not that the rain, but more probably the whirl itself, is the cause of the barometric depression, especially as mechanical principles teach us that in the midst of a rotating mass of air the pressure must decrease toward the axis of rotation? I therefore believe that in the present state of our knowledge of the phenomena of storms we must seek to explain the barometric minima of the storm centers by dynamical laws. A step in this direction has been made by Ferrel (see "Silliman's Journal," January, 1861; and "Nature," July, 1871).* I will renounce this view whenever any one shall have completely demolished the objections that can be raised against the origin of barometric minima in consequence of an ascending air-current without rotatory motion.

I have acknowledged that I have, in fact, expressed myself too generally in reference to an observation that one can with us note at any time, and Hoffmeyer remarks that in Denmark also the heaviest rains mostly occur during the lowest pressures. Of course, however, this does not prove that the rain must be the cause of the low pressure. This, and the justification of my statement, at least for all places that are protected from the south and southwest winds, will be shown by the following collation of the results of observations.

Wind-roses for Barometric Pressure and Percentages of Rainfall.

	Breslau.	Zechen.	Görlitz.	Zechen.	Vienna.	Vienna.	Berlin.	Eutin.	Elsfleth.	Utrecht.	Berlin.	Elsfleth.	Utrecht.
	Number of years of observation.												
	11	10	12	10	11	11	13	6	5	13	13	5	13
	Rainfall.			Barom.	Rain.	Barom.	Rainfall.				Barometer.		
NE	4	4	7	755.1	2	746.6	3	9	6	5	759.3	763.0	763.2
E	2	3	4	751.7	1	745.0	6	5	2	3	758.8	760.9	762.3
SE	5	4	3	750.0	5	744.2	4	15	4	7	754.7	760.1	760.0
S	9	12	3	749.7	3	742.5	7	10	12	17	751.3	757.3	757.9
SW	10	20	13	749.5	4	741.3	25	36	36	29	752.6	757.3	758.5
W	23	19	27	751.7	33	742.9	40	13	27	19	756.0	759.0	760.0
NW	27	23	34	752.8	44	744.8	9	10	10	14	757.6	760.8	761.3
N	20	15	9	754.7	8	746.7	6	2	3	6	758.7	762.8	762.8

On the lee side of the Alps (as at Vienna) and of the Riesengebirge [= Giant Mountains between Bohemia and Prussian Silesia] (as at Breslau, Zechen, and Görlitz), the greatest precipitation occurs with W. and NW. winds, but on the North German slope with SW. winds. Even here, however, the lowest pressure does not perfectly coincide with the max-

[*Note by the Translator.—Mr. Ferrel's first memoir, Nashville Journal of Medicine and Surgery, xi, 1856, and his elegant mathematical paper published in The Mathematical Monthly, 1859 and 1860, vols. ii and iii, appear not to have been accessible to Professor Hann.]

imum rainfall, and the wind-roses of Zechen and Vienna show that in fact it cannot be dependent upon the latter. The distribution of pressure in the wind-roses shows no dependence upon the distribution of rainfall, and this is further testimony that the rain cannot be the cause of the low pressure during S. and SW. winds. If we unite into one mean the corresponding values for the places having similar distribution of rain, we obtain the following more general series of figures:

	NE.	E.	SE.	S.	SW.	W.	NW.	N.	
Breslau, Zechen, Görlitz, and Vienna. Rain	3	2	4	8	12	26	33	12	A.
Breslau, Zechen, Görlitz, and Vienna. Barom	750.8	748.4	747.1	746.1	745.4	747.3	748.8	750.7	A.
Berlin, Elsfleth, and Utrecht. Rain	5	4	5	12	30	28	11	5	B.
Berlin, Elsfleth, and Utrecht. Barom	761.8	760.4	758.3	755.5	756.1	758.3	759.9	761.4	B.

If we start with the lowest barometric reading, and form the changes of pressure by passing from one wind-direction to the next, we obtain the following series of numbers:

Series A. *Maximum rain with NW. winds.*					Series B. *Maximum rain with SW. winds.*				
	SW.	W.	NW.	N.		S.	SW.	W.	NW.
Rain percentage	12	26	33	12	Rain percentage	12	30	28	11
Pressure changes	0	+1.2	+1.5	+1.9	Pressure changes	0	+0.6	+2.2	+1.6

Therefore, in spite of the increasing rainfall, as the wind veers from SW. to NW. the pressure increases by 3.4 millimeters in series A. If the rain caused the slightest sensible fall in pressure, then in the wind-roses for Vienna, Breslau, &c., the minimum of pressure would change from the south to the west side. But notwithstanding that only little rain falls with S. and SW. winds in Vienna, Breslau, &c., still the atmospheric pressure is lowest with these winds, precisely as at those places for which the maximum rainfall and the minimum pressure nearly coincide.

Since on the north slope of the Alps* and on the northeast side of the Riesengebirge, the heaviest precipitations occur on the southwest side of the storm center, therefore the latter should receive a tendency to remain stationary or even to retrogress. This deserves a further examination.

* Especially in the valley of Vienna. In Munich and Kremsmünster, the maximum rainfall appears to occur with west winds; but Vienna is also protected on the west by spurs of the Alps.

D.

THE LAWS OF THE VARIATION OF TEMPERATURE IN ASCENDING CURRENTS OF AIR, AND SOME OF THE MOST IMPORTANT CONSEQUENCES DEDUCIBLE THEREFROM.

By Dr. J. Hann.

[Translated by Cleveland Abbe from Zeit. Oest. Gesell. Met., 1874, ix, pp. 321 *et seq.*]

Only in the last ten years have we really begun to fully credit and establish physically the great importance of the ascending movement of air for a whole series of atmospheric phenomena. This, for instance, can be clearly seen when we seek to collect the sentences relating to the ascending currents in the carefully and comprehensively compiled Lehrbuch of E. E. Schmidt, Leipsic, 1860. Notwithstanding that the cooling of ascending air in consequence of expansion could long since have been computed by means of an equation deduced by Poisson, still we have made only fruitless efforts in its application to atmospheric phenomena, and, for instance, have sought to explain the precipitation on the flanks of a mountain over which a warm current is blowing mostly by the contact of the rising air with the cool earth, also by the mixture of the air with the higher colder strata. Evidently, it has been considered not quite certain how far the equation of Poisson is applicable to the processes in the free atmosphere; for there was no appropriate example at hand by means of which to demonstrate quantitatively the diminution of temperature with altitude in accordance therewith. The minute study of the Föhn phenomena first led to such knowledge, and showed the difference of temperature demanded by the theory between the lower and upper strata of a descending current of air and the circumstances which enforced the recognition of the connection between cause and effect.[1] The theory of ascending movements of air has, however, experienced a very important advance through the labors of certain physicists (W. Thomson, Reye, Peslin), who have deduced from the principles of the mechanical theory of heat the laws of the variation of temperature in ascending or descending dry or moist masses of air.

In our Zeitschrift we have as yet presented no report on these important labors, and as they have also not as yet been presented in the physical or meteorological text-books, we consider it proper here to explain and to deduce the most important propositions in the simplest manner possible.

1.

The Amount of the Diminution of Temperature in Ascending Currents of Air in which no Condensation of Vapor occurs.

Let dQ denote a very small quantity of heat imparted to or abstracted from a unit weight of air;

c, the specific heat of air at constant pressure $= 0.2375$;

dt, the slight change of temperature which is produced by dQ;

J, the mechanical equivalent of a unit of heat = 424 kilogram-meters;

K, the constant quantity $\frac{p_0 v_0}{273}$, which for the atmosphere equals 29.3,

and where p_0 is the pressure of one atmosphere upon a square meter = 10,333 kilograms;

v_0 is the volume of a unit of weight of air at the pressure p_0 and temperture 0° C.;

273 is the zero-point of the Celsius scale according to scale of absolute temperatures;

T, the temperature measured from the absolute zero-point = $273° + t$;

t, the temperature according to the Celsius scale.

We now have the equation[2]

$$dQ = c\,dt - \frac{R\,T}{J} \cdot \frac{dp}{p}.$$

If the mass of vapor rises, and if, as is the case in nature, heat is neither added nor taken away, its temperature will change, since under diminishing pressure p its volume increases. In this case, $dQ = 0$, and the connection between the temperature and the change of pressure is given by the equation

$$0 = c\,dt - \frac{R\,T}{J} \cdot \frac{dp}{p}.$$

For the slight elevation dh, the diminution of pressure dp is given by the equation

$$-dp = \rho\,dh,$$

where ρ is the density of the air under the pressure p.

From $pv = R\,T$ it follows, since

$$v = \frac{1}{\rho},$$

that

$$\rho = \frac{p}{R\,T} \quad \text{and} \quad -dp = \frac{p}{R\,T}\,dh;$$

whence

$$0 = c\,dt + \frac{1}{J}\,dh,$$

or, when the values of J and c are introduced,

$$\frac{dt}{dh} = -\frac{1}{Jc} = -0.009907;$$

the quotient $\frac{dt}{dh}$ represents the relation between the variation of temperature and of altitude, and therefore gives the change in temperature or the cooling of the rising mass of air for an ascent of one unit of length; that is to say, for one meter. Consequently, the cooling of the ascending air amounts to almost exactly 1° C. for every 100 meters, and remains the same no matter at what level the ascent begins[3] or what the

initial temperature may have been. Conversely, a descending current of air grows warmer at the rate of 1° C. per 100 meters.

If the rising air contains aqueous vapor, and if the latter is not condensed because the air remains relatively dry, and its ascent has not continued sufficiently high, then will the diminution of temperature be somewhat slower, since the specific heat of aqueous vapor (0.4805 according to Regnault) is somewhat higher than that of the air, but to so slight an extent that we can entirely neglect this retardation, and be entirely satisfied with the above adopted value of 1° C. per 100 meters. The weight of vapor contained in one kilogram of moist air is at the atmospheric temperatures so slight in comparison with the weight of the air, that the somewhat greater specific heat of the damp air can exert but little influence.

If q represents the weight of aqueous vapor contained in a kilogram of moist air;

$1 - q =$ the weight of the dry air:

$c' =$ the specific heat of the moist air, will be given by the expression

$$c' = 0.2375\,(1-q) + 0.4805\,q = 0.2375 + 0.2430\,q.$$

The value of q, which always remains a very small fraction, is found from the following equation:[4]

$$q = 0.623\,\frac{e}{p - 0.377\,e},$$

or very nearly

$$q = 0.623\,\frac{e}{p};$$

where e represents the tension of vapor, and p the total pressure or height of barometer when both quantities are measured by the height of a column of mercury. For instance, if the ascending air has at 30° C. a relative humidity of 60 per cent., for which $e = 18.9$ millimeters, then will $q = 0.01564$; whence $c' = 0.2413$, and the quotient

$$\frac{dt}{dh} = -\frac{1}{J\,c'} = -0.009751.$$

The change in temperature is therefore, for every 100 meters, only 0°.016 smaller than for dry air. The entire error introduced by extending the computation to 900 meters above which condensation follows amounts therefore only to 0°.14 C.

We may be allowed here to add some further remarks upon the relations between the temperature and pressure of the air. The formula previously found gives directly the change of temperature as dependent upon the change in altitude of a mass of air; we will now seek for a relation which expresses the change of temperature dependent upon a change of pressure. From the fundamental equation first laid down, it follows directly, if $dQ = 0$, that—

$$\frac{dt}{dp} = \frac{R}{c\,J} \times \frac{T}{p} = 79.23\,\frac{1}{p},$$

if for R, c, J, the values already given be introduced, and for T the value

273. From this equation, it follows that at the surface of the earth, or $p = 760$ millimeters, a change of temperature of 0°.104 C. corresponds to a change of pressure of 1 millimeter, so that a barometric fall of 20 millimeters corresponds to a cooling of 2°.1 C. But since such a fall in pressure requires with us, under the most favorable case, an interval of twenty-four hours, therefore are the changes of temperature resulting from this cause completely hidden by greater changes due to other causes, and I do not think it will be possible to demonstrate them. When, therefore, Sir John Herschel considers the rapid fall in pressure as a very frequent inducement to the formation of precipitations, which latter he calls barometric fogs, and minutely characterizes them at page 93 of his Meteorology, he therein evidently overestimates the fall of temperature due to this source. On the other hand, in the tropical cyclones, in which the air flows into a space wherein the pressure has been diminished by from 40 to 60 millimeters, sensible precipitations due to this cause can occur. The fundamental equation on page 23 can be written thus:

$$\frac{dp}{p} = \frac{c\,J}{R} \cdot \frac{dt}{T}.$$

The integration of this equation gives, if by p, T, and by p', T', we designate the values of pressure and absolute temperature that belong together,

$$\log \frac{p}{p'} = \frac{c\,J}{R} \log \left(\frac{T}{T'}\right),$$

or

$$\frac{p}{p'} = \left(\frac{T}{T'}\right)^{\frac{c}{R:J}};$$

since we have, as before shown,

$$c_p - c_v = \frac{R}{J},$$

then is

$$\frac{c}{R \div J} = \frac{k}{k-1},$$

where

$$k = \frac{c_p}{c_v},$$

or the ratio of the two specific heats of air; therefore,

$$\frac{p}{p'} = \left(\frac{T}{T'}\right)^{\frac{k}{k-1}},$$

or

$$\frac{p}{p'} = \left(\frac{273° + t}{273° + t'}\right)^{\frac{k}{k-1}} = \left(\frac{1 + a\,t}{1 + a\,t'}\right)^{\frac{k}{k-1}}.$$

But this is the well-known equation of tensions deduced in an entirely different manner by Poisson. The value of

$$\frac{k}{k-1} = 3.444, \qquad \text{or} \qquad k = 1.41,$$

can be deduced from the above given values of c, R, and J. Observations on the velocity of sound in the air give

$$k = 1.40, \quad \text{or} \quad \frac{k}{k-1} = 3.5.$$

Inversely,

$$\frac{k-1}{k} = 0.2907 \text{ or } 0.2857,$$

and with this we have

$$\frac{T}{T'} = \left(\frac{p}{p'}\right)^{0.29}.$$

From Poisson's equation we can also directly, and therefore without the assistance of the principles of the mechanical theory of heat, deduce the expression for the diminution of heat with altitude given on page 24, and may therefore represent it as a simple function of the density or the pressure of the strata of air at different altitudes. If we combine the equation

$$\frac{p}{p'} = \left(\frac{T}{T'}\right)^{\frac{k}{k-1}}$$

with the self-evident relation

$$\frac{p}{p'} = \frac{v'}{v} \cdot \frac{T}{T'},$$

we obtain

$$\left(\frac{v'}{v}\right)^{k-1} = \frac{T}{T'},$$

and thence

$$\frac{p}{p'} = \left(\frac{v'}{v}\right)^{k} = \left(\frac{\delta}{\delta'}\right)^{k}.$$

If in the equation $dp = \delta\, dh$ we substitute for dp the differential of

$$p = p'\left(\frac{\delta}{\delta'}\right)^{k},$$

integrate, and consider that

$$\left(\frac{\delta}{\delta'}\right)^{k-1} = \frac{T}{T'},$$

we find

$$\frac{T}{T'} = 1 - \frac{k-1}{k} \cdot \frac{\delta'}{p} \cdot h.$$

(William Thomson on the Convective Equilibrium of Temperature in the Atmosphere, Mem. Lit. and Phil. Soc. of Manchester, 3d series, vol. ii, 1865, read January 21, 1862.)

In this equation, T', δ', and p' are the values of temperature, density, and pressure that obtain at any moment in the initial stratum of air. For the surface of the earth,

$$p' = 10333 \text{ kilograms},$$

$$\delta' = 1.293 \cdot \frac{T_0}{T'},$$

where $T_0 = 273°$, corresponds to the zero-point of the Celsius scale. Since, therefore, we can now introduce Celsius's degrees instead of absolute temperatures, we find

$$t = t' - 0.009932 \,.\, h,$$

therefore again the constant diminution of temperature of 1° C. for every 100 meters, if we omit the consideration of the correction of the density for variation of gravitation.

2.

Determination of the Diminution of Temperature in an Ascending Current of Saturated Moist Air which continually condenses a Portion of its Vapor.

If, while the mass of air rises through the slight elevation dh, the small quantity dq of vapor be condensed, then will the quantity of heat $r\,dq$ be liberated, if r represents the latent heat of aqueous vapor at the prevailing temperature t. For moist air far removed from the point of saturation, we have found the equation

$$c'\,dt = -\frac{1}{J}\,dh,$$

in which

$$\frac{1}{J}\,dh$$

represents the equivalent of the quantity of heat which is abstracted from the mass of air, and goes over into the work of expansion, whereby the temperature sinks by dt degrees.

This quantity of heat drawn from the mass of air will now only in part affect it, since the liberated latent heat of condensation takes up the other part. Therefore the equation must now stand

$$c'\,dt + r\,dq = -\frac{1}{J}\,dh.$$

From

$$q = 0.623\,\frac{e}{p},$$

there follows

$$\log q = \log 0.623 + \log e - \log p,$$

$$\frac{dq}{q} = \frac{de}{e} - \frac{dp}{p};$$

whence

$$dq = q\,\frac{de}{e} - q\,\frac{dp}{p};$$

and, by substitution in the original equation,

$$c'\,dt + rq\,\frac{de}{e} - rq\,\frac{dp}{p} + \frac{1}{J}\,dh = 0.$$

Since now

$$dp = -\rho\,dh,$$

whence

$$-\frac{dp}{p} = \frac{\rho}{p} dh,$$

then will

$$c' dt + rq\frac{de}{e} + rq\frac{\rho}{p} dh + \frac{1}{J} dh = 0,$$

$$\left(c' + rq\frac{1}{e}\cdot\frac{de}{dt}\right) dt + \left(\frac{1}{J} + rq\frac{\rho}{p}\right) dh = 0;$$

and hence

$$\frac{dt}{dh} = -\frac{1 + rqJ\frac{\rho}{p}}{c'J + rqJ\frac{1}{e}\cdot\frac{de}{dt}}.$$

This derivation of the law of cooling of moist air is due to Peslin, who first gave it in his memoir "Sur les Mouvements Généraux de l'Atmosphère; Bull. Hebd. de l'Association Scientifique de France, tom. iii, 1868." Even before him, Sir William Thomson, in 1862, deduced a very similar relation, but the derivation given by Peslin is somewhat shorter and more elegant.

The quotient $\frac{dt}{dh}$ represents the diminution of temperature in the ascending moist mass of air for an elevation of one unit of length. The diminution of temperature is now dependent upon the quantity of vapor contained in the air, and is therefore variable according to the temperature at which the air is saturated with vapor. For $r = 0$, that is to say, in case no condensation occurs, the equation resolves itself into that already above given for dry air, as it should do.

In order to attain a more accurate insight into the changes of temperature of moist ascending air at different initial temperatures and different altitudes, it appears to be most convenient to compute and present in one table the values of $\frac{dt}{dh}$ for various values of e and q, which latter quantity also depends upon the pressure of the air. Previously, however, we must more closely consider the quantities that enter into the composition of the formula. The product $r \cdot gJ$ represents the mechanical equivalent of the latent heat of all the aqueous vapor contained in a kilogram of moist air, and its computation is subject to no difficulty; $\frac{\rho}{p}$ is a constant; if the density at the temperature 0° and at the normal pressure of one atmosphere (10333) is denoted by $D = 1.29277$, then, since $\rho = D\frac{p}{P}$, is 6.09730 the value of the logarithm $\frac{\rho}{p}$. Finally, the factor $\frac{1}{e}\cdot\frac{de}{dt}$ is computed most simply by means of the formula given by Magnus for the maximum tension of vapor for any temperature t. This formula reads:

$$e = 4.525 \times 10^{\frac{at}{b+t}}$$

where

$$a = 7.4475$$

and

$$b = 234.69.$$

If we take the logarithms and differentiate, we obtain

$$\frac{de}{dt} \cdot \frac{1}{e} = M \cdot \frac{ab}{(b+t)^2};$$

and after introducing the numerical values

$$\frac{de}{dt} \cdot \frac{1}{e} = \frac{[3.60472]}{(234.7+t)^2},$$

where the number inclosed in brackets is the logarithm of the product of $M\,a\,b$ ([5]), the latent heat r of aqueous vapor at different temperatures is computed according to the formula of Clausius,

$$r = 607 - 0.780\,t.$$

For the temperatures below 0° is still to be added the heat liberated on the passage of water from the fluid to the solid condition: it amounts to 80 calories. Since, however, at 0°, vapor can be condensed in a fluid form, I have computed the diminution of heat without including this additive heat for 0°. The differences are, however, quite unimportant, since, for 760 millimeters, we have $dh = 0.63$ for $t = -0°$, but $= 0.65$ for $t = +0°$; for 200 millimeters, we have $\frac{dt}{dh} = 0.38$ for $t = -0°$, and $= 0.40$ for $t = +0°$.

The table thus computed is as follows:

Diminution of Temperature for each Hundred Meters of Ascending Saturated Air, in Centigrade Degrees.

Initial pressure.	Initial temperature.									Altitude for 0°.
	−10°.	−5°.	0°.	5°.	10°.	15°.	20°.	25°.	30°.	
Millimeters.	°	°	°	°	°	°	°	°	°	*Meters.*
760	0.76	0.69	0.63	0.60	0.54	0.49	0.45	0.41	0.38	20
700	.74	.68	.62	.59	.53	.48	.44	.40	.37	680
600	.71	.65	.58	.55	.49	.44	.40	.37		1,910
500	.68	.62	.55	.52	.46	.41	.38			3,360
400	.63	.57	.50	.47	.42	.38				5,150
300	.57	.51	.44	.42						7,430
200	.40	.43	.38							10,670

Value of q in grammes or the weight of the aqueous vapor in a kilogram of saturated air.

Millimeters.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Meters.*
760	1.7	2.6	3.8	5.4	7.6	10.5	14.4	19.5	26.3	20
600	2.2	3.2	4.6	6.8	9.6	13.3	18.3	24.8		1,910
400	3.3	4.8	7.2	10.2	14.4	20.0				5,150
200	6.5	9.7								10,670

Value of $\frac{1}{e} \cdot \frac{de}{dt}$ *in units of the fifth decimal.*

	7971	7628	7306	7005	6721	6455	6204	5967	5744

The preceding tables give in a convenient manner answers to all questions that relate to the temperature of an ascending saturated current of air. If the ascending air is not saturated with moisture, its cooling follows at first the laws for dry air, and the figures of the above table first come into application when the cooling has reached the dew-point.

But before we draw any further conclusions, we must first refer to the equation for the expansion of saturated moist air which Reye has deduced (see "Die Wirbelstürme, p. 215, or Schlomilch, Zeitschrift Math. und Physik, 1864). It is the analogue of Poisson's equation for the elasticity of dry air. If we designate by x and x' the specific quantity of vapor for the absolute temperatures T and T' (that is to say, the maximum weight in kilograms of the vapor contained in one cubic meter), by n the initial pressure in the atmosphere, by r and r' the latent heat of aqueous vapor at the temperatures T and T', and, instead of the numerical coefficients, write their logarithms within brackets, we obtain the following equation:[6]

$$\log\left(\frac{p}{p'}\right)=\left(3.4438+[8.61417]\frac{x'\,T'}{n}\right)\log\frac{T'}{T}+\frac{[8.25195]}{n}\left(x\,r\,\frac{p'}{p}-x'r'\right).$$

This formula enables us, for a given initial and final temperature and a given initial pressure (in atmospheres), to compute the pressure corresponding to the final temperature. For instance, the initial temperature of a moist current of air which rises from the earth's surface, where $n=1$, is 20° C., or $T'=293°$; and if we desire the pressure, or the altitude at the moment when the temperature has sunk to 10° C., or $T'=283$, then we have $x'=0.01715$, $x=0.00936$ kilograms, $r_0=592.6$, $r=599.5$, and there results

$$\log\frac{p}{p'}=0.23660+0.100235\,\frac{p'}{p};$$

by means of many trials, we find from this,

$$\frac{p}{p'}=0.780,$$

or a barometric pressure of

$$0.780\times 760=593 \text{ millimeters.}$$

This for a mean temperature of 15° C. corresponds to an altitude above sea-level of 2,105 meters. The average diminution of temperature of the ascending current is therefore 0°.47 C. per 100 meters. Using our table, page 29, we should, starting first with 20°, have found 0°.45 C. per 100 meters, or approximately 10° in 2,200 meters, therefore at a pressure of somewhat less than 600 millimeters. Since now for 10° and 600 millimeters, according to the table, the diminution of temperature is 0.49 per 100 meters, therefore the mean diminution is 0.47, and the exact elevation for a cooling of 10° is given, as above, almost without computation.

If, however, we inquire with what temperature a saturated moist cur-

rent of air arrives at a given altitude, and this is the usual question in meteorological investigations, then we cannot use the above equation, because it already assumes a knowledge of the final temperature; on the other hand, our table gives at once abundantly sufficient information. The initial temperature of the current of air may, for instance, be 10° C., and the altitude to which the air must rise = 8,000 Paris feet = 2,600 meters. The table first gives approximately the cooling = 0°.54 × 26 = 14.0, therefore a final temperature of −4°. At the altitude of 2,600 meters for −4°, the temperature diminution is 0.61. The mean temperature diminution is therefore 0.57 per 100 meters, and at 8,000 Paris feet, or 2,600 meters, the temperature is −4°.8 C. The error that we introduce would be quite unimportant if for such slight altitudes we only used the initial rate of diminution of temperature. While a moist current of air cools by only 14°.8 C., a dry current would cool 26°, and therefore show a temperature of −16° C. If now the air sinks on the other side to its original level, it is warmed by 26°, whether dry or moist. The temperature of the dry current of air is therefore the same on both sides of the mountain, that of the moist current, however, 21°.2 C., that is to say, by more than 10° C. higher on the lee side. Since the air is only saturated with moisture at −4°.8 C., it must possess a great relative dryness. Thus, as is well known, is explained the warmth and dryness of the Föhn.

We will now append some general conclusions to the derivation of the law according to which a mass of air changes its temperature when the pressure acting upon it, and therefore its volume experience a change.

For a moment imagine the attraction of the earth upon its atmosphere to cease, and the latter to be a uniformly dense gaseous envelope, having a constant temperature at all distances from the earth's surface. This gaseous envelope contains no aqueous vapor, and the influence of every cosmic or telluric source of heat is excluded; then let the force of gravity come into existence: the lower strata of air are, by the weight of the upper, compressed together, and the density of the strata diminishes with the altitude, and, according to Mariotte's law, in a geometrical progression. The temperature also can now no more remain the same at all distances from the earth's surface, but must be highest in the lowest strata, which are strongest compressed, and must diminish upward. The law of this upward diminution of temperature is expressed by the equation of Poisson, above given, which presents the relation between the temperature and the pressure of the gas to which no heat is communicated from the exterior, and from which no heat is abstracted, and we have shown, page 25, that the amount of this diminution of temperature is 1° C. for 100 meters difference of altitude. In the gaseous envelopes of other celestial bodies, a diminution of temperature outward must take place in a similar manner, which, so far as it is a function of the gravitation toward the center of the mass, can be computed according to one of the formulæ given on pages 23 and 24. The amount of this

diminution of temperature depends therefore on the specific heat of the gaseous envelope and the magnitude of the force of gravitation on the surface of the body in question.[7]

The equilibrium of heat that obtains in the atmosphere under such a distribution of temperature will best be especially understood by the consequent deduction, that any mass of air transferred from one altitude to another will, in consequence of the compression or the expansion that it experiences, there attain exactly the temperature of the surrounding region, and will therefore have no tendency to leave its new location. This is a state of indifferent equilibrium. If the diminution of temperature were less than 1° C. per 100 meters of ascent, then would the equilibrium be "stable"; were it greater than 1° per 100 meters, then would the equilibrium of the superposed strata be "unstable."

If now we let the sun act as the source of heat for our atmosphere, and assume that the latter is perfectly diathermanous, so that it absorbs absolutely no heat-rays, and therefore receives the solar heat only through the medium of the heated surface of the earth, the stratum of air directly resting upon the earth becomes heated by conduction, specifically lighter, and ascends, a process that is continually renewed. Since now, in ascending masses of air, a cooling must take place at the rate of 1° C. per 100 meters, therefore the already existing law of the diminution of temperature with altitude cannot be altered by this method of warming from beneath. The assumed premises are, however, only in part fulfilled in the actual atmosphere, and its heating takes place by no means in such a simple manner. First, the atmosphere is by no means perfectly diathermanous, but directly absorbs about one-fourth of the solar heat-rays. Moreover, for the higher strata an important source of heat is the aqueous vapor, which, carried up with the ascending air or cooled from any other causes, condenses and gives its latent heat up to the air, and in this way diminishes its cooling. The table on page 29 shows to what a great extent the cooling of moist ascending air is retarded. A further [third] source of heat is the radiation from the heated surface of the earth, a considerable portion of which may be absorbed in the lower strata. Inversely, the surface of the earth cooled by radiation of heat at night and in winter has a cooling influence on the lowest strata of air. All these circumstances bring it about that observations give a diminution of temperature with altitude varying according to place and time, and which cannot be expressed by any law. Observations agree only in showing that on the average in the lowest strata, which alone are accessible to us, the temperature diminution is considerably slower than 1° C. per 100 meters, and that the annual average in the tropics, as in Europe, lies between 0°.5 and 0°.6 C. The few observations made by Glaisher above 20,000 feet give a still slower temperature diminution at that altitude.

A temperature diminution as rapid as ascending currents of dry air must show has only been found in summer time during fine weather.

quite near the earth's surface. Glaisher's observations, during numerous balloon voyages, gave, for the free atmosphere, the following ratios for the diminution of temperature with altitude (Report of the British Association, 1864):

Diminution of Temperature per 100 *meters in Celsius degrees.*

Weather.	Altitude in thousands of English feet.							
	0–1	1–2	2–3	3–4	4–5	5–10	10–15	15–20
Clear	0.98	0.71	0.55	0.55	0.55	0.46	0.39	0.30
Cloudy	0.86	0.73	0.73	0.56	0.55	0.45	0.40	0.25

This gives for the summer season, up to an altitude of 5,000 English feet (1,500 meters), an average diminution of temperature of 0°.68 C., very nearly equal to that observed in the Alps. The observations therefore show the mean condition of the atmosphere to be that of stable equilibrium. The diminution of temperature with elevation is slower in winter (in Switzerland it is 0.45) for two reasons: First, because then the earth's surface exerts a cooling influence on the lower strata, and often so intense that the temperature increases upward; to a less extent this is also the case at night. Secondly, because the condensation of aqueous vapor takes place during this season most frequently in the lower strata; often, indeed, at the surface itself of the earth. But of most importance is the first-named circumstance, for on clear days and in clear winter months the diminution of temperature with the altitude is slower than during cloudy weather or precipitation. The difference of temperature (8° C.) between Geneva and St. Bernard (difference of altitude 2,070 meters) is in December less than it would be in a current of moist air, saturated at 20° C., blowing from Geneva to St. Bernard. The slight difference of temperature can therefore not be explained by means of the heat of condensation; it is in by far the greater part to be ascribed to the greater cooling of the lower strata by the earth's surface and to the underflow of the air cooled upon the mountains.

In summer, the diminution of temperature is more rapid, because then the heated surface of the earth acts more powerfully by conduction and radiation upon the lowest strata of air. Since this stratum for the same reason is at this time relatively drier, wherefore the first condensation of vapor occurs at higher altitudes, the ascending air can show a diminution of temperature nearly the same as for dry air.

We ought, however, not to represent to ourselves the warming of the atmosphere from below on calm, clear summer days as taking place by means of a continuous ascending current. Above limited localities, such a process certainly occurs, and the cumulus formations are a proof thereof. But, in general, the warming proceeds gradually from below upward, through the rising of warmer and sinking of cooler air and their intermixture, and the work of one day is continued on the next

after the nocturnal interruption. During the night-time even warmer strata can float above the lower ones, cooled at the surface of the earth, until the insolation is again active. In this manner, during calm, clear summer weather, the entire lower portion of the atmosphere is quite uniformly warmed and stirred up.

If the ascending masses of air reach that altitude at which their temperature agrees with that of the stratum attained, then should we, during beautiful summer weather, observe a diminution of 1° C. per 100 meters. This, however, is not the case, and the observations show, on the contrary, that, at least in mountainous countries, the temperature diminishes with the altitude slower during fine weather than during bad weather. This has already been proven by Kämtz from the temperature differences between Halle and the Brocken. In order to attain a better insight into this relation, I have deduced the following numbers:

An excellent monograph has been published by Billwiller in Zürich on the thunder-storm of 28th July, 1872, in Northern Switzerland (Schweiz. Meteorolog. Beobachtungen, Jahrg. 1872). It therefore seems to me most instructive to investigate the diminution of temperature with altitude for the period immediately preceding this storm. Up to the 19th July, the weather was cloudy and rainy; the last rain fell on the 19th, and on the 20th there began a period of beautiful hot summer weather, which experienced its first interruption on the 28th by heavy thunder-storms in the afternoon.

Daily Mean Diminution of Temperature in degrees Celsius per 100 meters.

Station.	Altitude.	Date, July, 1872.					Monthly mean.
		15–19.	20–24.	24–28.	29.	30.	
	Meters.						
Rigi Vitznau	1374	0.73	0.43	0.34	0.51	0.53	0.60
Chaumont-Neuchatel	664	0.74	0.54	0.56	0.94	0.64	0.68
Gotthard-Altdorf	1639	0.64	0.47	0.46	0.54	0.63	0.60
St. Bernard-Montigny	1980	0.72	0.60	0.55	0.53	0.63	0.66
Mean		0.71	0.51	0.48	0.61	0.61	0.63
Mean cloudiness		6.8	1.8	1.7			4.7
Weather		Rainy, cool	Hot...	Hot...			

During the rainy period, therefore, the upward diminution of temperature was very large; on the advent of clear hot summer weather, it became smaller, and, in fact, the diminution progressed quite regularly from the beginning of the fine weather to the outbreak of the thunder-storms, for instance:

Station.	July.				
	19.	20.	21.	27.	28.
Rigi Vitznau	0.63	0.45	0.35	0.29	0.30
Gotthard-Altdorf	0.67	0.53	0.51	0.49	0.46
St. Bernard-Montigny	0.75	0.54	0.63	0.56	0.52

The rapid rate of diminution of temperature during the rainy period, which was also accompanied by strong winds, is a consequence of the ascent of the air on the flanks of the mountains. In the free atmosphere, the air at the same altitudes is certainly somewhat warmer and the temperature diminution slower. I do not, however, think that in the subsequent slower rate of diminution the radiation of heat from the surface of the earth exerted any disturbing influence. Such radiation acts upon the thermometer more at the lower than at the upper station, and must therefore tend to increase the differences of temperature. It can, however, not be denied that the true temperature of the air in the neighborhood of a mountain is somewhat higher than at the same level in the free atmosphere. But the observations of Glaisher up to 5,000 feet elevation have given during fine weather an average rate of diminution of only 0°.67 C. per 100 meters. Even during the afternoons, the diminution of temperature with altitude does not reach the degree that corresponds to that of an ascending current of air.

Rate of Diminution of Temperature at 1h p. m.

Stations.	July, 1872.		
	15–19.	20–24.	24–28.
Rigi Vitznau-Gersau	0.79	0.53	0.49
Chaumont-Neuchatel	0.81	0.81	0.72

Thus it seems that the warming of the lower strata of the atmosphere by the heated surface of the earth takes place mostly by the gradual mixing of the lowest strata with the higher, whereby the ascending columns of air with a slower movement gradually equalize their temperature with that of the surrounding air without reaching those altitudes to which a continually ascending current of air of equal temperature could attain; the heating of the air by the radiation from the earth's surface must also come into consideration. Thus there is formed a stratum pretty uniformly heated up to a certain altitude above the earth's surface within which the diminution of temperature takes place slowly, but above which it probably takes place rapidly. So long as the dry winds which bring clear weather blow strongly, the upward diminution of temperature is rapid, because the particles of air warmed below must attain their appropriate altitude; but as soon as the dry winds diminish, and calms finally ensue, the above described overheated stratum of air develops itself continually more and more, and with it first an indifferent, then, finally, perhaps, an unstable equilibrium between this and the higher strata. From the 20th to the 28th of July, 1872, the warming from below had gradually extended above the level of the highest station in Switzerland, and, therefore, before the outbreak of the thunder-storm no unstable equilibrium is demonstrable. But on the 28th, when the stronger west wind first prevailed high above Switzer-

land, the stagnating overheated stratum of air could no longer remain in equilibrium, and a stormy mixture of the lower and upper masses of air, which of course was accompanied with precipitation and thunder and lightning, precipitated itself mostly from the upper strata in special localities downward to the earth's surface.

The occurrence of unstable equilibrium in strata of air lying vertically above each other after a period of sunny and calm weather is facilitated by the fact that the inflow of a strong wind almost always first occurs in the upper strata, whose temperature thereby rapidly sinks, while in the lower strata, it perhaps still rises. Since the flow of the air near the surface of the earth is much obstructed and delayed by friction and other obstacles, the cooling is completed more rapidly in the upper strata and the inflowing colder air surrounds from above the warmer lower strata, which then must break through with violence.[8]

In a sinking and warming current of air, no condensation of aqueous vapor can take place, therefore in it the increase of temperature of 1° C. per 100 meters, as required by theory, must clearly stand forth. In fact, the Föhn wind shows this rapid increase of temperature between the summit and base of the mountains over which it descends. In general, descending masses of air can have only a warming effect upon the earth's surface, since their increase of temperature is more rapid than the average upward diminution of temperature. If, for instance, in summer the strata in which float the ice crystals of the cirrus clouds at altitudes of 6,000 to 7,000 meters had a temperature of even — 30° C., still would they by sinking to the earth's surface have a temperature of +30° or +40° C. Only in the case of a diminution of temperature of more than 1° C. per 100 meters, which can, however, only be local and occur in summer, but never in winter can it happen that masses of air descending from the upper regions to the earth's surface arrive there cooler than the air that they displace.[9]

One of the effects of descending currents of air must consist in clearing up the sky, and dissipating the precipitations, instead of causing them. Now, however, we still observe precipitation on the advent of an upper current of air that slowly descends to the earth's surface and then brings warmth. When, after clear weather, the increasing cirrus clouds announce the speedy advent of foul weather, one can often enough clearly observe how the layer of cirro-stratus sinks, and is thereby thickened, and gradually merges into a rain-cloud. Often after a hot summer day I have seen thunder-storms form in this manner; the formation of the lower layer of cumulo-stratus unmistakably proceeded from a layer of sinking cirro-stratus. In this case, however, the upper current of air could be relatively so cold that even after sinking it could cool the lower strata. In winter, such an assumption would not be allowable; we must assume that the upper warm current increases in volume, continually extends into deeper strata (but does not form a descending air-current), and by mixing with the lower strata produces a precipitation continually

increasing with the depth, but still, as is well known, always of slight intensity; (the precipitation on the east side of the windrose, where the polar current merges into the equatorial).

At least, this much is clear, that the view now very prevalent that the upper trade-wind or the SW. currents of our hemisphere bring a large part of its aqueous vapor from its place of origin, the equatorial calm zone, is not tenable. At the low temperature that it must have in the high region above the trade-wind, it can, even if saturated, only contain so little water, that, sinking down to the earth without the addition of water from below, it can only arrive with a great relative dryness. Thus, for instance, the observations of Piazzi Smyth on the Peak of Teneriffe, at the lower limit of the return trades, at an altitude of 326+ meters, gave the average tension of vapor for August and September at 4 millimeters, therefore a dew-point of -2° C. This current could therefore first produce a precipitation in regions whose temperature lay below -2° C., and therefore it is impossible that our summer and autumn rains come from this source. Karl v. Fritsch confirms the slight amount of moisture in the anti-trades upon the Peak of Teneriffe, and says that the higher SW. wind has a cooling, not a warming, effect [10] (probably on account of its greater violence). Muhry imagines the water contained in the anti-trade to be in the solid form of the ice spiculæ of the cirrus clouds, and, indeed, the upper SW. current could carry with it some water in solid form. But if the material for the abundant precipitation of our SW. and W. winds comes in this manner from the zone of calms, or from any part of the tropical zone, then the upper west current above the zone of trade-winds must cover the sky with a thick dark cirro-stratus layer, while to the contrary the zones of trade-winds are the clearest regions of the earth.

Therefore the rains of the anti-trades and of the west winds of higher latitudes do not originate in the tropics, but the anti-trade receives its moisture anew first from below, and can take up much water since it is warmed by descending, and can again condense it so soon as it is cooled in its horizontal progress or by ascent upon mountains.

If no aqueous vapor could condense in ascending masses of air, then must their ascensive power be rapidly paralyzed, since the cooling of the ascending air is much more rapid than the usual upward diminution of temperature. Therefore dry ascending air-currents could only under rare, specially favorable circumstances attain to great altitudes. So soon, however, as vapor is condensed, the temperature diminution of the ascending air is so delayed that its ascensive power becomes very powerful, and since thereby again the intensity of the precipitation increases, the upward impulse remains in power until the aqueous vapor has nearly exhausted itself. Since now the diminishing pressure of the air partly compensates the diminution of the quantity of vapor (see table, page 29), therefore the buoyancy diminishes only slowly. The ascent of the damp air is finely displayed in the rapid growth of the cumulus clouds, which

often rise like columns in the blue sky of summer, and plainly grow outward from the interior. The warmer the air, or the higher the temperature at which it is saturated with vapor, by so much the greater is the upward impulse it experiences on the occurrence of precipitation. Therefore the precipitations of the ascending currents in summer, and especially in most tropical climates, occur under the most favorable circumstances. When, during calm, sunny weather, the above-described overheating of the lower strata of air, which is always accompanied by abundance of aqueous vapor, has been brought about, and there arises, if only in the highest strata, a disturbance of the equilibrium already stretched to its utmost limit, and thereby a small initial condensation of the vapor, the air immediately receives a strong upward impulse, and draws the lower strata rapidly with it in motion. Hence the numerous thunder-storms in calm, hot summer weather, and in the tropics on the cessation of the regular trade-wind. These thunder-storms do not indicate a change in the weather: they only restore the equilibrium of the atmosphere disturbed in a vertical direction. The lower atmospheric strata are cooled by evaporation and by the cooler rain-water; the upper are warmed, and thus the equilibrium becomes again stable.

The formation of hail is, as Reye has shown, most easily explained by such ascending moist currents of air. The occurrence of hail in the hottest time of the day and the year and the prevailing calms point directly to the superheating of the lower strata as their immediate cause. But the chief difficulty consists in the question, Whence comes the cold that is necessary for freezing the precipitation, and how can it be due to the high temperature of the lower strata of air? Mohr assumes a descent of higher cold air. We have previously shown how seldom this process can occur, and that it can produce no considerable cooling, because the air is greatly warmed in its descent. Most natural is it to assume with Reye, inversely, that the lower, moist, hot air is rapidly carried upward. We have previously explained that on the occasion of irruption of cold winds the upper strata rush ahead of the lower, so that the stagnating lower, hot, moist air is equally surrounded by the upper cold air. The former thereby acquires an especially strong upward impulse, which is increased by the intense condensation, so that it must soon arrive at altitudes where the precipitation freezes. This explains the fall of hail on the advancing side of a thunder-storm or tornado; its recurrence in bands; its dependence upon local peculiarities (broad river valleys are more intensely warmed, and have no equalizing currents of air, such as in narrow mountain valleys; therefore hail is more frequent in the former, as has, for instance, been demonstrated for Carinthia by Prettner); the descent, by way of compensation, of the cooled air; finally, the maximum of hail in early summer, at which time the upward diminution of temperature is most rapid, and the greatest difference of temperature exists between the earth's surface, warmed by the high sun, and the upper strata of air, that still retain their winter cold.

Since moist air, so soon as precipitation occurs therein, must almost always experience an impulse upward, because the upward diminution of temperature is seldom so slow as to correspond to that of an ascending moist current of air, therefore it seems to me that in all precipitations the ascending movement of the air plays an important part and increases its intensity. When a cooler air-current begins to flow over warmer air, there first occurs at the surface of contact a slight precipitation, above which then the air breaks with strong ascensive power upward into the upper cold air, in consequence of the continually increasing difference of temperature, and thereby loses almost the whole of its aqueous contents. On the other hand, if a warmer current flows above a cold one, this process must be feebler; and therefore the precipitations are less intense when warmer air approaches.

Since the effect of the precipitations of the rising moist air is to elevate the temperature of the upper strata, but to lower that of the lower strata, it follows that a barometer at the earth's surface can remain quite unaffected by this re-establishment of the equilibrium in a vertical direction of the temperature; but at a certain altitude, the barometer must, before the rain, stand higher than afterward. The diminution of pressure caused by the abstraction of the elastic force of the aqueous vapor is compensated by the inflowing air of the neighborhood. In extended rains, a relatively warmer air collects above the rain-clouds, but an active ascension of this air can only take place at the edges, where the difference of temperature produces a strong upward impulse, and the cooler air of the neighborhood can rapidly flow in after. Also, in the case of a condensation of vapor over an extended area, the barometer will sink somewhat only in the central portions. We have no observations of this, because any such precipitation must immediately produce currents of air from the sides inward; but with the accession of cooler air, the warming of the higher strata is again compensated, and the barometer will rather rise than sink. The causal relation between the precipitations and the origin and the progress of storms can therefore only consist in this, that the condensation of aqueous vapor gives the air a more or less decided upward impulse,[11] and thereby produces and continually maintains a flow of air from all sides toward the rain-cloud. But so long as no whirl is produced thereby, this process causes no notable change in atmospheric pressure in the horizontal strata of air. Therefore the heaviest rainfalls are, in the equatorial zone, accompanied by no low barometer, nor in our latitudes either, so long as the causes leading to the formation of a whirlwind are wanting. The pressure sinks decidedly only when an extended whirl has formed, in whose center probably the air is rising with increased violence. I therefore believe the diminution of pressure in the center of a storm-area to be a mechanical effect of the whirling movement of the air. This whirl, however, continually receives new force, and is controlled by the process of precipitation. I therefore agree with Reye

when he says that in the whirlwinds the moving force is the latent heat of the condensed aqueous vapor.*

The results of the investigations of Ley and Blanford into the origin of whirlwinds agree, as I believe, entirely with the preceding presentation of the case, that the barometric minimum at the center of a cyclone is primarily a consequence of the whirling movement of the air; for it does not happen that in consequence of extended heavy precipitations a decided barometric depression forms over a region about which then the air begins to circulate, but it is only after the whirl is well developed that an area of low pressure forms, which then progresses further. From the weather prevailing over the Bay of Bengal previous to the Calcutta cyclone of 1867, Blanford has drawn the conclusion that the cyclones originate in a region of calms and variable winds between the northeast monsoon and the retreating southwest monsoon. Their primary cause consists in local accumulations and condensations of aqueous vapor in a calm region above the ocean. Many days elapse before the whirlwind has developed itself (Proceedings of the Royal Society, 1869). Similar are the conclusions of Ley as to the origin of whirlwinds in England.[12]

There still remains unexplained, so far as I can see, the cause which determines the different intensities of the barometric minima in the centers of storms in the tropics and in our latitudes in the summer and winter. If the intensity of the precipitation determined this, then would the barometric minima of the summer exceed those of the winter,[13] but it seems more promising to seek for the cause of the greater intensity of the barometric depressions in winter in the greater differences of temperature. The air over the warm Atlantic Ocean, strongly warmed by frequent precipitations, is then bounded on both sides by very cold dry air. This must give rise to decided disturbances of equilibrium and to storms; but, on the other hand, in the tropical cyclones the temperature differences can have no relation to the intensity of the storm.

That in the condensation of aqueous vapor in winter the latent heat of fluidity is, in the case of the freezing of water, to be added to the latent heat of vaporization, can only make a slight difference, because the former amounts to only a little over one-eighth of the latter (see page 29). The ratio of the liberated heat at 15° C. to that at —5° C. is as 596 to 690 or as 1 is to 1.16. Herein, therefore, the explanation cannot lie, as Espy, and in part also Reye, assumes. Rather could we think that the circumstance that in winter the condensation takes place in lower, denser strata of air, and at lower temperatures, should increase the upward tendency. In fact, this must be the case, but, as a simple computation shows, the buoyancy of a mass of air is, for the same temperature differences, only about one-fifth smaller when the pressure is 600 millimeters instead of 760 millimeters, and only

[* NOTE BY THE TRANSLATOR.—This theorem will also be found accepted by Ferrel: *Mathematical Monthly*, ii, 1858.]

about one-tenth smaller when such temperature differences occur at 15° C. instead of 0° C. Even if we consider also the greater latent heat, this still does not compensate for the differences in the intensities of precipitation, and suffices not for an explanation of the whole of the difference of the barometric depressions of the summer and winter, so long as we consider the intensities of the whirlwinds proportional to the intensities of the precipitations.

NOTES.

No. 1, p. 22. See Zeit. Oest. Gesell., vol. x, p. 573. The Siroccos of the Southern Alps.

No. 2, p. 23. For those of our readers to whom this important equation seems strange, and who have neither time nor inclination to look up its demonstration as derived from the fundamental principles of the mechanical theory of heat in the treatises of Clausius or the text-book of Zeuner, we will endeavor to give in the following as simple demonstration as possible.

A mass of air, as is well known, needs a smaller quantity of heat to raise its temperature by 1° when we prevent its expansion than when it is allowed to expand. We will denote by c_v the quantity of heat which a kilogram of air requires in the first case, that is, when the volume v is constant; and by c_p the quantity required in the second case, when the pressure p remains constant, and equal to that of the exterior.

The difference between c_v and c_p the latter being the greater, arises from the fact that in the case of expansion by heat there is also exterior work performed, which consists in the pushing back of the exterior pressure p through the small space dv, which is the extent of the expansion.

The amount of this work is $p\,dv$, and the quantity of heat which is thereby consumed is $\frac{1}{J}p\,dv$, where $\frac{1}{J}=\frac{1}{424}$ is the equivalent of heat for the unit of work. Consequently the quantity of heat dQ which is communicated to the mass of air is divided into two parts; the one is the equivalent of the increase of temperature of the kilogram of air, the other is the equivalent of the work of expansion, as is expressed in the following equation:

$$dQ = c_v\,dt + \frac{1}{J}p\,dv.$$

The combined law of Mariotte and Gay Lussac reads, as is well known,

$$\frac{p\,v}{1+\alpha t} = \frac{p'v'}{1+\alpha t'},$$

where $\alpha = 0.003665 = \frac{1}{273}$ is the coefficient of expansion of the air. If we divide the denominators of both members by α; put $T = 273 + t$, and for the case when $t' = 0$ put $R = \frac{p_0 v_0}{273}$, we obtain the simplest form of this law in the expression $p\,v = R\,T$, whence follows

$$p\,dv + v\,dp = R\,dt,$$

$$p\,dv = R\,dt - v\,dp;$$

$$dQ = c_v\,dt + \frac{R}{J}\,dt - \frac{1}{J}v\,dp,$$

$$dQ = \left(c_v + \frac{R}{J}\right)dt - \frac{1}{J}v\,dp.$$

According to what has been above said, the difference $c_p - c_v$ is equal to the quantity

of heat consumed in the expansion ($a\,r$) of the air for an elevation of 1° of temperature; that is,

$$\frac{1}{J} \times a\,v_0 \times p_0 \text{ or } \frac{1}{J} \cdot \frac{v_0 p_0}{T^0};$$

whence

$$c - c_v = \frac{1}{J} \cdot \frac{v_0 p_0}{T_0} = \frac{R}{J},$$

or

$$c_v + \frac{R}{J} = c_p;$$

whence

$$dQ = c_p\,dt - \frac{1}{J}\,v\,dp.$$

Since, however,

$$v = \frac{R\,T}{p},$$

and for c_p generally c is written, there results the important equation given in the text.

No. 3, p. 23. So far as the change of the intensity of gravity with altitude can be neglected, J is, indeed, an absolute constant; but the unit of weight, the kilogram with which we measure J, needs a correction for gravity.

No. 4, p. 24. The weight P of dry air in a cubic meter is

$$P = \frac{S_0}{1 + a\,t} \cdot \frac{b - e}{760};$$

where S_0 is the specific gravity of the air, b is the barometric pressure, e is the tension of vapor. The weight of the aqueous vapor is

$$p = 0.623\,\frac{S_0}{1 + a\,t} \cdot \frac{e}{760}.$$

The sum of both weights gives the weight of a cubic meter of moist air:

$$P + p = \frac{S_0}{760} \cdot \frac{b - 0.377\,e}{1 + a\,t}.$$

The volume of the unit's weight (kilogram) of this air is therefore $\frac{1}{P+p}$. And since in the unit of volume (a cubic meter) there are contained p kilograms of aqueous vapor, therefore in the volume occupied by a kilogram of moist air there is contained

$$\frac{p}{P+p} = 0.623\,\frac{e}{b - 0.377\,e} \text{ kilograms of aqueous vapor.}$$

No. 5, p. 29. Zeuner, in the second edition of his "Grundzüge der mechanischen Wärmetheorie," gives a table of the values of $\frac{de}{dt} \cdot \frac{1}{e}$ (Table I a, column 5) for each 5°, and computed by Regnault's formula. For the temperatures that we here have to do with, the formula of Magnus agrees completely with that of Regnault, but the latter gives a complicated and inconvenient expression for our quotient.

No. 6, p. 30. I have given a slightly different form to this equation, and have introduced the constants used throughout this essay. I consider it unnecessary to give the process of deduction of this formula, since the work of Reye, "Ueber die Wirbelstürme," is easily accessible to every reader, which is not true of the treatises of William Thomson and Peslin.

No. 7, p. 32. This conclusion is limited by the limit of applicability of the Mariotte law at high and low pressures. Since by the recent investigations of Liljeström and others it is made probable that the Mariotte law loses its rigid exactness at low pressures, it follows that we ought not to apply to very low pressures any formula that is founded upon it. All theoretical conclusions as to the height of the atmosphere and

the temperature of the upper strata must for the present be suppressed until the behavior of gases under very low pressure has been sufficiently studied.

Moreover, in any case, we must introduce into the above-mentioned formula the correction for variation of gravity, if we would extend its application to great distances from the earth's surface. We thus find a rate of diminution of temperature outward continually slower and slower, which, like the attraction of the earth, approaches the limiting value *zero*.

No. 8, p. 36. I have observed, in the case of the thunderstorms approaching Kremsmünster from the west, that their violence was almost always less; indeed, they generally did not come to a discharge [of lightning?] if the storm began before the cloud was near the zenith.

No. 9, p. 36. We do not here consider the descending winds in valleys between mountains, which, indeed, owe their origin to great differences of temperature.

No. 10, p. 37. Petermann's Geog. Mitth., 1866, p. 220.

No. 11, p. 39. To avoid the mistake that we have previously shown to be very widespread, we should not say "the condensation warms the air," but "it diminishes the cooling." The latent heat will not be liberated without a cooling takes place; nor can it ever be sufficient to even compensate for the cooling [much less to overcompensate and warm up the air] to a sensibly higher temperature.

No. 12, p. 40. Also what Jahncke says upon the weather preceding the West India hurricanes agrees therewith. (Quarterly Journal of the Met. Soc., vol. ii, p. 89.)

No. 13, p. 40. Also the summer season has extended precipitations of similar great intensity. I recall, for instance, the uninterruptedly rainy period of August 15 to 19 of this year (1874), whose extent and intensity caused the extraordinary floods in all the rivers of Central Europe. A barometric minimum preceded this. During the rain the pressure rose.

E.

THE LAW OF THE VARIATION OF TEMPERATURE IN ASCENDING MOIST CURRENTS OF AIR.

Letter of Prof. Dr. L. Sohncke, of Carlsruhe.

[Translated by Cleveland Abbe from the Zeitschrift für Met., 1875, x, pp. 56–58.]

By your memoir on ascending currents of air, &c., published in the Zeitschrift for last October and November, you have, as it seems to me, rendered a great service to the friends of a genuine scientific meteorology. Sir Wm. Thomson's and Peslin's labors on this subject appear to have been known to a very limited extent. They were unknown to me, and are not even accessible to me here in Carlsruhe. Especially important is your development of Peslin's formula for the diminution of temperature in the ascent of a saturated current of air, for the table, page 29, has a fundamental importance in all questions bearing on this point. Under these circumstances, it seems proper that I should call your attention to a mistake which has slipped into the computation of the table, affecting the last decimal of many of the numbers therein. On page 28 you say, let $\frac{\rho}{p}$ be a constant, since $\rho = D\frac{p}{\delta}$,

&c., although it follows from the law of Mariotte and Gay Lussac that $\frac{\rho}{p}$ has the value $\frac{1}{RT}$ as you yourself* have used it, page 23.

Furthermore, in the deduction of the formula of Peslin, the approximate value of q, $0.623\,\frac{e}{p}$, is used, whereas the introduction of its true value offers no difficulty. Considering these two circumstances, the expression for $\frac{dt}{dp}$ receives a somewhat different form, which I will here deduce.

In the equation that applies to a change of condition of any gas,

$$dQ = c\,dt - \frac{RT}{J}\cdot\frac{dp}{p},$$

the left-hand side is 0 if dry air changes its condition without addition or subtraction of heat. But if it is moist saturated air that ascends without receiving heat from the outside, then we can use the preceding equation by putting for dQ, not 0, but that heat which is liberated by the condensation of the elementary quantity dq of aqueous vapor. Let the specific heat of moist air be c'; for moist air the constant R can very approximately retain unchanged its former value 29.3; the equation then becomes

(1) $$-r\,dq = c'dt - \frac{RT}{J}\cdot\frac{dp}{p}$$

The left-hand member has the minus sign, because it represents a positive quantity of heat, and dq is a negative quantity, namely, the diminution of the quantity of vapor there present. To this we add the equation

(2) $$dp = \rho\,.\,dh,$$

which expresses the diminution of pressure with altitude. In case that the ascent of a moist current in dry air is considered, then for ρ the specific gravity of dry air is to be taken, since in a narrow, slightly rotating current the pressure can differ only extremely little from the pressure at equal altitude outside.

Since now

$$\rho = \frac{1}{v} = \frac{p}{RT},$$

* I have, in fact, on page 28, put

$$\frac{\rho}{p} = \frac{1}{RT_0} = \frac{1}{29.3 \times 273},$$

whereas it should have been

$$\frac{1}{29.3 \times (273 + t)},$$

where t is the temperature in Celsius degrees. Since, however, t is always small in comparison with 273, this assumption of T_0, instead of T, has only a very slight influence upon the result. The introduction of an approximate value for q materially simplifies the numerical computations.—J. Hann.

there follows, from equation 2,

(3) $$-RT\frac{dp}{p}=dh.$$

Further, the quantity of vapor q present in one kilogram of saturated air, or

$$q=\frac{0.623\frac{e}{p}}{1-0.377\frac{e}{p}},$$

gives the equation

$$\frac{dq}{q}=\frac{de}{e}-\frac{dp}{p}+\frac{0.377\left(\frac{de}{p}-e\frac{dp}{p^2}\right)}{1-0.377\frac{e}{p}}$$

$$=\frac{\frac{de}{e}-\frac{dp}{p}}{1-0.377\frac{e}{p}}$$

(4) $$=\frac{\frac{1}{e}\cdot\frac{de}{dt}dt+\frac{dh}{RT}}{1-0.377\frac{e}{p}}.$$

By means of equations (3) and (4), equation (1) now becomes

$$\frac{-rq}{1-0.377\frac{e}{p}}\left(\frac{1}{e}\cdot\frac{de}{dt}dt+\frac{dh}{RT}\right)=c'\,dt+\frac{dh}{J};$$

whence—

(I) $$\frac{dt}{dh}=-\left\{\frac{\frac{1-0.377\frac{e}{p}}{J}+\frac{rq}{RT}}{c'\left(1-0.377\frac{e}{p}\right)+rq\frac{1}{e}\cdot\frac{de}{dt}}\right\}.$$

This formula differs from yours in the introduction of $\frac{1}{RT}$ instead of $\frac{\rho}{p}$ and also by the occurrence of the factor $\left(1-0.377\frac{e}{p}\right)$ in both the numerator and denominator. If, according to this formula, we compute $\frac{dt}{dh}$ for the case $\left(\begin{matrix}t=10^\circ\text{ C.}\\p=760^{\text{mm}}\end{matrix}\right)$, we find $\frac{dt}{dh}=-0.00534$, whereas your table gives -0.0054.

In case the problem concerns the ascent, not of a narrow current, but of a great mass of air, it is questionable whether it is not more correct

to substitute for the density ρ in equation (2), which determines the diminution of pressure with altitude, the specific gravity of moist air, or

$$\rho' = \frac{p}{RT} \cdot \left(1 - 0.377 \frac{e}{p}\right),$$

where p is expressed in kilograms per square meter. By this step, the only change in the preceding equation is that dh everywhere receives the additional factor $\left(1 - 0.377 \frac{e}{p}\right)$. Therefore in this case the diminution of temperature is that given by equation (I) multiplied by the same factor, or,

$$\text{(II)} \qquad \left(\frac{dt}{dh}\right) = \frac{dt}{dh}\left(1 - 0.377 \frac{e}{p}\right).$$

The introduction of the specific gravity ρ' of moist air instead of dry in this case is analogous with the consideration of the moisture of the air in barometric hypsometry, and means the ascent of moist air in the midst of air equally moist, providing that under these circumstances an ascent on a large scale actually occurs.

In the preceding example $\left(\begin{matrix} t = 10^\circ \\ p = 760\,\text{mm} \end{matrix}\right)$, we find by formula (II)

$$\left(\frac{dt}{dh}\right) = -0.00532,$$

or scarcely an appreciably different result.

F.

RAINFALL AND BAROMETRIC MINIMA.

By Prof. Dr. Theo. Reye.

[Translated by Cleveland Abbe from the Zeitschrift d. Oest. Gesell. Meteorologie, 1875, x, p. 65–70.]

From one of the recent memoirs of Dr. Hann I perceive, to my delight, that in the most important points our views as to the cause of whirlwinds already agree. [Hann's memoir was written in December, 1874, before the publication of his review of Ferrel's theories.] We both recognize the latent heat of the condensed vapor as the moving force in whirlwinds; this gives to the air a stronger or weaker ascensive force, and thereby causes a continuous inflow of air toward the rain-cloud. In general, I agree with what Hann says: "The atmospheric pressure sinks first when an extended whirl has formed in whose center the air probably is rising with increased vehemence." For I also am persuaded[1]

[Note by the Translator.—As there is frequently much confusion of ideas as to the part played by aqueous vapor in storms, the translator hopes to contribute somewhat toward clearer views by adding to the present collection this paper of Reye's with Hann's foot-notes.]

[1] See my "Wirbelstürme," page 138.

that the rotatory motion contributes considerably to the increase of the central depression, and that only through it does the duration of the barometric minima, often for weeks, become possible; and in my opinion the fact that no cyclone has ever yet been observed in the neighborhood of the equator finds an equally simple and sufficient explanation in the absence of any motive toward a rotatory movement.

Only in one not unimportant point do our views still differ. I think:[2] "The ascending current of air can only continue so long as its temperature, in consequence of the liberated latent heat of the vapor, exceeds on the average that of the neighboring air-strata. But, on account of this higher temperature, the pressure under the ascending current must be less than that on the borders of the cyclone." On the other hand, Hann says: "The condensation of the atmospheric aqueous vapor has no sensible influence on the change of atmospheric pressure; the low barometer in the storm-center can, therefore, not be explained by precipitation." Mohn's theory of the advance of cyclones toward their rainiest side is therefore reliable or not, according as mine or Hann's view is correct.[3]

Hann establishes his principle chiefly upon his reduction of 146 heavy rainfalls in Batavia, that are recorded in the three-years' hourly observations of Dr. Bergsma. The barometer rose at the commencement, and during the first two hours of the rainfall, on an average about 0.35 millimeter, but fell again about 0.1 millimeter within the two hours following the rain, and therefore, after the rain, stood always 0.25 millimeter higher than before it. "This slight increase of pressure," Hann very correctly thinks, "is a secondary effect of the condensation of the vapor; that is to say, it is produced by the cooling of the lower air-strata by the raindrops that fall down from higher, colder strata, and by the cooling due to evaporation. Perhaps, also, the concussion of the falling water and of the air dragged along with it contributes somewhat to the initial rapid rise of the pressure."

To these purely local observations at Batavia we can now oppose a longer series of observations, that embrace an extended country, and lead to opposite conclusions, namely, the daily observations that were made about 1850 in the United States by numerous naval and Army officers, and by 163 private individuals. James Espy for years entered these upon synoptic charts. From more than 1,800 such charts he draws, principally for the winter months, the definite conclusion:[4] "In all great and sudden depressions of the barometer there is much rain and snow, and in all sudden great rains or snows there is a great depression of the barometer near the center of the storm and rise beyond its borders."

Loomis, whom we also thank for other very important works on tornadoes and storms, has lately discussed the weather-maps of the United

[2] See this Journal, viii, p. 177; compare, also, my "Wirbelstürme," p. 132.

[3] See, on the other hand, ix, pp. 344, 345, and x, p. 69.

[4] Espy, *Fourth Meteorological Report*. Washington, 1837. p. 10, Generalization No. 9.

States for 1872 and 1873 with special reference to storms. The paths of the storms during 314 days were examined; the mean direction of their progress was very nearly from west to east.[5] "One circumstance seems to have a decided influence upon the modifications of the storm-paths—this is the rainfall. Every considerable barometric depression is accompanied by rainfall, and the area over which the rain occurs generally extends much farther on the eastern or forward side of the central depression than on the western." And the farther the rain-area stretches on the east side of the storm, so much the more rapidly does the storm advance in this direction. By separating the cases in which the storm-track had a direction more to the north or south, Loomis further found that the direction of the storm-path in 24 hours very nearly agreed with that toward which, in the preceding *eight hours*, the rain-area had extended the farthest. If the greater axis of the region of rain was directed toward N. 53° E. or N. 118° E., then the mean direction of the corresponding storm-tracks was N. 40° E. or N. 116° E. "The agreement would certainly have been still greater if we could have made the comparison with the direction of the storm-tracks in the next 8 hours instead of 24."

Since the beginning of 1867, in the Norwegian Meteorological Institute, the most important meteorological observations at 210 European stations have been, day by day, graphically presented upon a chart. By these charts, Mohn establishes the fact that on the front or east side of the storms the tension of the vapor and the quantity of cloudiness increases, and that there heavier and longer continued rain or snow prevails; on the hinder or western half, however, the vapor-tension falls, the cloudiness diminishes, and the rain is light.

The barometric minima of the Torrid Zone are regularly accompanied by the heaviest rains, and, according to Thom,[6] the condensation of vapor stretches much farther on the front than on the hinder side of the cyclone. The island of Mauritius, to which numerous vessels repair after every great storm, afforded for many years a very favorable position for the study of tropical whirlwinds to Thom and to its meteorological society, still flourishing under Meldrum's guidance. Thom explicitly says that no phenomenon accompanies these storms so regularly and is so astonishing as the enormous mass of water falling from the moving masses of air. "Hundreds of miles distant, on all sides of the whirlwind, extends a thick stratum of clouds that pours out rain in torrents and unceasingly. This process continues week after week, and is apparently characteristic of a hurricane in all its stages. The approach of such a storm can almost be predicted from the unbroken layer of clouds that slowly covers over the heavens, at first at a great altitude, gradually, however, descending to the lower strata and accompanied by increasing darkness,

[5] Loomis. See Zeitschrift, Bd. i, pp. 245–251, and American Journal of Science, 1874.

[6] Thom, An Inquiry into the Nature and Course of Storms in the Indian Ocean, South of the Equator. London, 1845. pp. 202, 206.

until at last it rests upon the earth and begins to rain. These signs are recognizable at a distance of 200 or 300 nautical miles from the hurricane."

These accordant results of extended systems of meteorological observations in America, Europe, and the South Indian Ocean, especially the important fact *that the barometric minimum advances toward the side of the heavier precipitation*, plainly show the appreciable influence of the condensation of the atmospheric aqueous vapor upon the change of atmospheric pressure. Furthermore, the known laws connecting the tension and temperature of aqueous vapor and of the atmosphere force us to assume some such direct influence. Local observations like those at Batavia can, in my opinion, not prove the contrary, since they leave us entirely in ignorance as to the extension of the rainfall and as to the simultaneous meteorological phenomena of the surrounding portion of the globe. The enormous rainfall of 2d and 3d December, 1872, which overflowed the whole of Carinthia, Carnatia, Görz, Northern Venetia, and Southern Tyrol, has shown in what distant regions many times we must seek the prime cause of very heavy and extended rains.[7] Certainly at that time no one on the south flank of the Alps suspected that this rain was caused by a barometric minimum on the coast of France; and even to-day it would be inexplicable to us why that enormous precipitation did not at least cause a secondary minimum,[8] unless we had an accurate knowledge of the configuration and the atmospheric conditions of half of Europe.

So far as concerns the 146 heavy rainfalls at Batavia, these appear, so far as concerns their duration and geographical extension, to have had the characters of local thunder-storms; for among them those of more than three hours' duration were so infrequent that Hann could not give any average for the fourth hour of rain. Now, in the case of local storms, even when they are accompanied by heavy precipitation, the accompanying rarefaction can very rapidly be restored, because the region of condensation occupies a relatively very small space in an immense atmosphere. Moreover, the process of condensation, *i. e.*, the formation of the storm-clouds, begins at least in our latitudes, generally a considerable time before the outbreak of the storm; and if during the subsequent rain the pressure rises a little by reason of the cooling of the lowest stratum of air, I therein find nothing contradictory to the theory.[9]

[7] Compare this, Zeitschrift, vol. viii, pp. 103, 179.

[8] If a sensible barometric depression could be caused by rain, then certainly here at least a secondary minimum must have been formed!—J. HANN.

[9] To this I remark in brief only as follows, but in general refer to pages 11 and 12 of this present volume x [see the preceding translation (C) of Hann's reply to Hoffmeyer's remarks].—J. HANN.

In reference to the rains at Batavia, I have submitted the heavier short rains to computation, because these must best represent the effect of an ascending current of air, and because an examination of the whole series of observations showed me at once

My own and Hann's views as to the part played by aqueous vapor in meteorological processes differ from each other, as I believe, much less than they appear to do. I also, for partly well recognized reasons, attribute no special importance to precisely the same results of my computation that Hann opposes. On this point allow me to make the following remarks: My computations "On the Expansion of the Air of the Atmosphere in the Formation of Clouds," as I first published them eleven years ago ["On Vertical Currents of Air in the Atmosphere," Schlomilch, Zeitschrift für Mathematik und Physik, 1864, Bd. 9, pp. 250–276; also, Reye, "Wirbelstürme," Hannover, 1872], had for their immediate object the overthrow of Mohr's theory of the formation of hail. Mohr maintained that because saturated steam has a much greater volume than the water from which it is formed, therefore by the condensation of the vapor at any point in the atmosphere there must be formed an "immense" diminution of volume; this "formation of a vacuum" is, however, followed by a strong indraft, an inrush of air, especially from the upper strata, which then, by reason of their own cold, cause a new condensation, etc. In opposing this theory, it was sufficient for me to assume that the air in which this condensation occurs loses no heat during the process. [10]

With the same assumption, at the end of the chapter, I compute, incidentally, the quantity of air that will be pushed out of a vertical column

that in no instance, not even those of longer duration (and there occur many of twelve hours and over), did a sensible influence of the rain make itself apparent. The phenomena are here precisely the same as Sykes gives for the Dekkhan (see Zeitschrift, x, p. 12). There are, indeed, no data at hand relative to the extent of these rains, but we know that at the rainy season, for instance in January, there are on the average of seven stations in the Sunda Islands 21.3 days, and there must be a truly wonderful arrangement if it does not occasionally rain simultaneously over nearly the whole Archipelago, the more so since the rains occur very nearly at the same time of day. And yet there is no disturbance of the diurnal period of the barometer! And what rains were those compared with ours! On the 10th January, 1867, there fell in one hour at Batavia 97 millimeters, that is to say, only 3 millimeters less than falls with us in three months, from December to February, when we have the lowest barometric pressure. In this case, no minimum occurred, even at a great distance, that one could quote as an excuse for any decided diminution of pressure.

The facts quoted by Espy, Thom, and Loomis prove nothing against my assumption, because the influence of the rain can only become prominent in the case of rainfalls without an accompanying rotatory motion of the air, but where there is no whirl there is also no notable barometric minimum. On this is founded the inductive portion of my reasoning. On the other hand, I will readily allow that small differences of pressure (I have expressly said "no notable influence") can, perhaps, be brought in agreement with the results of the observations in Batavia; the land and sea breezes of the tropics show that quite unnoticed barometric differences can bring about very active currents of air. Such slight differences of pressure as these are quite sufficient to cause the continued flow of air toward that place in the whirl where condensation takes place, and to explain its continuance and the direction of its progressive movement, as I have already indicated on pages 292 and 344, vol. ix [see page 13, § B, and page 39, § D, of the preceding translations of Hann's articles].—J. HANN.

[10] Then, however, no condensation could occur; therefore, also, no evolution of heat and no expansion; and all further consequences likewise fall to the ground.—J. HANN.

of atmosphere by the condensation of one millimeter of rain; and, under the further assumption that this excess of air can be immediately removed, and is not replaced at the earth's surface by cooler air flowing in from the side, I arrive at the theoretically not uninteresting result, that a barometer under such a column of air must fall to the extent of three-fifths of the depth of rain fall. In all this, however, I was perfectly aware, and have even so stated, that the assumed conditions do not occur in nature. Therefore have I, also, at no time, neither in the text of my book on "Wirbelstürme" nor elsewhere, referred to this result of computation, and readily acknowledge with Hann, who assails it, that it has no practical importance. Still I believe as before, "notwithstanding perhaps this computation throws some light upon the low barometer that is so often observed in connection with the revolving storms that are accompanied by heavy rain."

In fact, the assumptions in question are approximately fulfilled in the case of the precipitations accompanying revolving storms; at least, far more nearly than in local thunder-storms, or in quiet, uniform, general rains. Since the air rises very rapidly in the interior of a whirlwind, therefore it and the aqueous vapors or cloud-fog that are carried up with it cannot lose much heat, either by conduction or by radiation; at the same time, however, the inflow of the lower mass of air from either side is hindered by the centrifugal force and the outflow of the upper layer is facilitated. But this theoretical result is not applicable without further considerations, even to the revolving storms; for, even if in these we have accounted for the heat which is consumed in the expansion corresponding to the latent heat liberated by the vapor, still there remains unnoticed that quantity of heat which is equivalent to the living force of the whirling mass of air and to the work of expansion performed in consequence of the ascension. For this reason, in my theory of whirlwinds, besides the very complete collection of observations, I refer only to the law of tension of saturated air and to the computations in reference to the unstable equilibrium in the atmosphere.

G.

ON THE RELATION BETWEEN THE DIFFERENCE OF PRESSURE AND THE VELOCITY OF THE WIND ACCORDING TO THE THEORIES OF FERREL AND COLDING.

By Dr. Julius Hann.

[Translated by Cleveland Abbe from the Zeitschrift of the Austrian Meteorological Association, 1875, vol. x, pp. 81–106.]

The historical developments of scientific theories, like those of political questions, have their reactionary periods, which, in both cases, are generally called forth by an excessive one-sided pursuit of some principle

which in itself may be correct. One of the best examples of this is found in the history of the geological views current in Germany in the course of the nineteenth century; but I believe that also the development of the theory of storms can be considered as a similar example. I will not here give a history of storm theories, but only briefly sketch, so far as it seems important for my purpose, the two opposed views; the older, which is still found almost exclusively in our German textbooks of meteorology, and the newer, which, proceeding in the beginning from America, and recently from the most northern states of Europe, has also already found influential supporters in Southern Europe.

The older theory considers the storm-whirl, if I may so express it, as purely mechanical, arising from the meeting of different currents of air. The centrifugal force arising in consequence of the rotatory movement of the air was held to be the cause of the low barometric pressure in the center of the whirls. We have lately heard this theory more fully expounded by Dr. Wittwer in this journal [vol. x, pp. 1-6]. The new theory, which I would designate as the physical theory, finds in the formation of some local diminution of pressure the first cause of an inflow of air from all sides and the attendant formation of a whirl in consequence of the influence of the earth's daily rotation. The barometric depression itself is viewed as a consequence of the condensation of the aqueous vapor over an extensive portion of the earth's surface [see this journal, vol. vi, pp. 209, 246, and vol. viii, pp. 109, 177].

As we perceive, the difference between these views consists, besides the diverse explanation of the origin of the whirl, also in this, that the older theory explains the differences of pressure as due to the wind; the new theory, on the other hand, deduces the direction and strength of the wind as phenomena resulting from the previously existing differences of pressure.

Both theories cannot stand together. It is, however, not therefore necessary that the one should be absolutely false and the other thoroughly correct. There may be in each correct and incorrect views mingled together. Wherefore we will examine them in reference to this.

No one can deny that whirls can arise by the conjunction of currents at an angle with each other. But how in this manner the invariable rotation from right to left in the northern and inversely in the southern hemisphere should arise, it would be difficult, indeed impossible, to explain. Still more difficult is it to explain, according to this theory, the fact that the whirl, once formed, pursues a path of hundreds of miles through the atmosphere, in the course of which it continually draws new masses of air into motion, overcomes a great amount of frictional resistance along its entire path, and exerts powerful mechanical effects. This would be physically impossible, and surpasses even the "perpetual motion" without a constant accession of force. It must, on the other hand, appear to every one as a pure play of the imagination to

assume a perpetually renewed conjunction of winds in the necessary direction continuously along the whole length of the storm-path through the most diverse systems of currents.

The new theory of the origin of the rotatory movement through the deviating influence of the earth's rotation upon the air currents flowing toward the area of least pressure fully explains the invariable direction of rotation from right to left in the northern and from left to right in the southern hemisphere. It also satisfies us especially in that it points to the source whence the whirl when once formed steadily derives new force. To this end it utilizes the fact that every great whirlwind is accompanied by an abundant condensation of aqueous vapor. The latent heat liberated by this condensation causes a more rapid ascent of air over the whirlwind and thus induces beneath it an inflow of the air from all sides. We now see that the whirl can progress, indeed, that it must progress if it is to have duration. The force that it needs to overcome the frictional resistance, to draw in hitherto quiescent masses of air, to bring about its powerful mechanical effects,—this force is already stored up above in the atmosphere in the neighborhood of the path along which it will pass. It remains latent until the approaching storm liberates it. The whirlwind must quickly come to a stand when it does not find sufficient aqueous vapor in the atmosphere and at the same time has great frictional resistances to overcome.

Since in this way this newer theory affords us a sufficient physical reason for some of the most important phenomena observed in connection with storms, I have allowed myself to briefly call it the "physical theory."

We must, however, consider the explanation of the barometric minima as due simply to the condensation of aqueous vapor as not to an equal extent satisfactory. I have already in this journal sufficiently fully expressed my views as to the reasons that necessitate the rejection of the view that by means of the condensation of aqueous vapor any considerable diminution of pressure at the earth's surface can be produced. [See vols. viii, p. 102, ix, p. 289, and x, p. 11.] A principle correct in itself has been pushed to extreme conclusions, to which the theory gives no foundation and facts afford no agreement. Whoever desires to see this one-sided application pushed to its extreme, may read the work of Hopkins "On the Atmospheric Changes," and Laughton's "Physical Geography." With many meteorologists at present the aqueous vapor is the great resort in every time of need, as was electricity, under the influence of Volta's ideas.

When one thinks himself obliged to reject a theory that appears to explain satisfactorily one group of phenomena, he also to a certain extent assumes the duty of offering a better one. I have, however, just as I was forced to think of attempting this duty, had the happiness to find that this is no longer necessary; that in fact other and better men have already done this.

I have already remarked (vol. x, p. 12) that I believe that the greatest part of the barometric depression in storms must be explained in some mechanical way. This is a return to the older theory, and one could in this respect consider me as reactionary.

It is remarkable that the newer theory of storms no longer utilizes the centrifugal force, and that it entirely overlooks a further influence similar to centrifugal force, although it perfectly recognizes its necessity in deriving the direction of the wind. The older theory utilized the centrifugal force to explain the diminution of pressure in the center of the whirl; but as yet I have nowhere found, at least in German writings, that any one has shown us, not even approximately, how great the barometric differences resulting from the centrifugal force of the rotating masses of air can be, or whether it suffices to explain the greater part of such depressions as occur in cyclones.

It is here the place to promptly say that one should never attempt to explain all barometric differences as consequence of the movement of the air. This extreme is to be avoided precisely as is the other. Our view is only that the larger part of the observed great differences of atmospheric pressure in a whirlwind, or even in a directly progressing current of air so far as any exist, is a consequence of the movement of the air. This latter movement is, however, itself the result of an original slight but more general variation of pressure.

We have quite recently heard Reye defend the view that a condensation of aqueous vapor over an extended portion of the earth's surface must cause a fall in the pressure of the air in consequence of the increase of temperature that takes place at the place of condensation. From a theoretical point of view, but little objection can be brought against this view. But it is impossible even to estimate how great the consequent actual fall in pressure may be even under any given circumstances; and since we know from observation that where the most rain falls the irregular variations in the barometer are not great enough to disturb the regular diurnal period, whose amplitude in favorable cases amounts to 3 millimeters, therefore we may conclude that the influence under discussion must have a less effect than this. On the other hand, from known principles of mechanics, we must necessarily conclude that the movement of the air once set up must of itself bring about differences of pressure that are ten or fifteen times greater. We can therefore scarcely be in doubt as to how we are to explain the great variations of pressure observed in the extra-tropical regions.

At the same time that I was writing out for this journal my thoughts adverse to pushing Espy's theory too far, Professor William Ferrel, of Washington, published a memoir (American Journal of Science, vol. viii, Nov., 1874) in which he endeavored to express mathematically the variations of pressure occurring in storms as a consequence of the centrifugal force and of the earth's rotation. In this memoir, however, he merely especially elaborates and accommodates to the present state of

our knowledge of storms an idea that he had already, in 1861, published in more general form in Silliman's American Journal of Science.*

In reference to the currents and pressures of the air in cyclones in low latitudes, we possess an excellent mathematical investigation by the genial Danish engineer Colding, well known as one of the founders of the mechanical theory of heat. Since, however, his work appeared in the Danish language, in the Proceedings of the Academy of Copenhagen, certainly but few meteorologists outside of Scandinavia will have become acquainted with it, and we will, therefore, pretty fully reproduce it in a later number of this journal. [See Paper I, which translation was made in 1873 directly from the original, with but few corrections, suggested by a subsequent comparison with Hann's German version.—C. A.] Colding considers the tropical cyclones as true whirls, in which the air rotates about a vertical axis, and the differences of pressure from the center to the edge of the whirl computed by him under this assumption agree perfectly with the observed values.

Of course we cannot assume that there exists in our whirlwinds any rotation of the mass of air in the sense that it several times or even once revolves about the center: the air moves apparently in spiral paths toward the center. This, however, is no reason why, even in the smallest portions of the curved path, the centrifugal force should not have its influence according to the prevailing radius vector and velocity. [Buchan is therefore in error in denying the influence of centrifugal force. *Hand Book of Meteorology*, 2d edition, p. 281.] The analogous influence of the earth's rotation is to be added thereto, and the consequence of both these influences is that the atmospheric pressure at the earth's surface diminishes toward the center of the storm-area. Especially does the influence of the earth's rotation explain simply and naturally the frequently immense extension of the area of much diminished pressure in the higher latitudes, while it is impossible to explain barometric minima of such extent by means of an ascending current of air or by precipitation.†

In order to make somewhat clearer the influence of the rotation of the earth upon the origin of barometric differences in a mass of air in motion, I will assume a definite case, and for simplicity assume a storm-wind advancing in a straight line.

Let us assume a southwest storm, extending from Northern Scotland to the foot of the Alps, or over about ten degrees of latitude, as often occurs. The velocity of the wind at a short distance above the earth's surface will, at 30 meters per second, not be assumed unusually great.

* [NOTE BY THE TRANSLATOR.—See some account of Ferrel's works in the note on page 72.]

† In reference to this see R. H. Scott's memoir "On Recent Progress in Weather Knowledge." The magnitude of the depressions affords an argument against their being simply due to the condensation of vapor, for on November 22, 1869, barometrical readings were reduced to the extent of nearly an inch from what they had been on the 21st, over an area of about 200,000 square miles. On January 20, 1873, the deficit of atmospherical pressure amounted to about $\frac{1}{20}$ of its total amount over the United Kingdom.

The earth's rotation will exert its influence upon this current of air; and under the simultaneous influence of gravitation and the deviation to the right in consequence of the rotation, the level surfaces, or surfaces of equal pressure, can no longer remain parallel to the earth's surface, but must ascend toward the southeast.

If we designate by

n the angular velocity per second of the rotation of the earth,

$$n = \frac{2\pi}{8616.4};$$

φ, the geographical latitude; then will

$n \sin \varphi =$ the deviation to the right, or the apparent turning which a moving particle experiences, as is shown in elementary physics;

$v\, n \sin \varphi$ will therefore be the linear deviation where

v is the path described in the unit of time, and consequently

$2\, v\, n \sin \varphi$ is the corresponding acceleration [*Beschleunigung*].

If we designate by

h the ascent of the level surfaces for a breadth b of the current of air, and by

g the acceleration [*Beschleunigung*] due to gravitation, the following equation must then obtain:

$$g \cdot \frac{h}{b} = 2\, v\, n \sin \varphi,$$

or

$$h = \frac{2\, b\, v\, n \sin \varphi}{g}.$$

From this equation (which has already been previously applied to the computation of the elevation of the water on the right bank of our rivers in consequence of the earth's rotation, and which must also hold good for currents of air) can be computed the ascent from northwest to southeast of the level surfaces in our current of air. If we take for φ its mean value 53°, and for b 1113 kilometers, we find

$$h = 396.5 \text{ meters}.$$

Therefore the surfaces of equal pressure are elevated by 396 meters from northwest to southeast, which corresponds to a difference of pressure of 37.7 millimeters of mercury. In our present case, therefore, simply in consequence of the influence of the earth's rotation upon the southwest wind, the pressure must diminish by 38 millimeters from the northern slope of the Alps to the northern portion of Scotland. I see no way by which we can evade this conclusion. *Owing to the rotation of the earth, a current of air must always, in the northern hemisphere, be accompanied by a diminution of pressure on its left side.* But this diminution of pressure corresponds to a condition of equilibrium so long as the movement of the air, or the quantity v, remains the same. There are, therefore, barometric depressions (and so-called barometric gradients), and very large ones too, that are the consequences of air currents which

were themselves first produced by the depression. The diminution of pressure at the earth's surface is increased when the air moves not in rectilinear but in curvilinear paths, since then the ordinary centrifugal force also comes into play. It is now customary, as is well known, to designate by the term "barometric gradient," or "the gradient," the difference of pressure for a given amount of distance, and in issuing "storm warnings" one deduces the strength of the future wind from the magnitude of the gradient. We have just shown that the greatest part of an observed gradient is not the cause but the result of the violence of the wind. For practical storm predictions, however, this is, of course, immaterial. In general, the so-called "Buys Ballot's law" is only the shortest expression for the facts graphically presented upon the synoptic charts, and it is therefore not affected by the vagaries of the theories of the origin of areas of low pressure.

We believe we have now reached a point of view from which the labors of Ferrel and Colding gain an increased interest; from which also, at the same time, the limits of their applicability may be perceived, and we can therefore proceed to their memoirs.

The title of Ferrel's memoir reads: "Relation between the Barometric Gradient and the Velocity of the Wind" (Amer. Jour. Sci., vol. viii, 1874).

The following is not a translation, but a sort of working over of Ferrel's text. Especially have we deduced equation (I) in a more elementary way, and also given it a somewhat different form.

When water has a motion of rotation in a stationary basin, the centrifugal force produced by the rotation causes the water to retreat from the center, and to acquire a funnel-shaped surface ascending toward the edge of the vessel. In consequence of this, the pressure on the bottom of the basin increases from the center toward the circumference. If

r is the distance from the center of the basin,
u the angular velocity of the rotation,

then will

$r\,u^2$ express the magnitude of the centrifugal force.

But in case the basin itself has also a rotatory motion in the same direction, whose angular velocity we designate by ω, then will the expression for the magnitude of the centrifugal force be

$$r\,(\omega + u)^2 = r\,(\omega^2 + 2\,\omega\,u + u^2) = r\,\omega^2 + 2\,\omega\,v + u\,v,$$

because $r\,u$ is the linear velocity of the movement of the water relative to the basin. Now the increase of pressure or the gradient in the direction from the center toward the circumference depends on this quantity $[r\,u]$. If, however, we refer the gradient to the surface of the water when at rest with respect to the basin, which latter, however, itself has an angular velocity ω, then in the above expression we must omit the term $r\,\omega^2$, which depends simply upon ω, and the expression for the centrifugal force becomes

$$2\,\omega\,v + u\,v = (2\,\omega + u)\,v.$$

In the case of a cyclone on the earth's surface of comparatively slight extension, and for which therefore the curvature of the earth's surface can be neglected, we have a phenomenon quite similar to the preceding. In addition to the rotatory movement of a cyclone relative to the earth's surface there is also to be considered the proper motion of the latter, one component of which corresponds to the turning of a disk about a center. In the elementary text-books of physics, in connection with the explanation of Foucault's pendulum experiments, it is demonstrated that the magnitude of this horizontal component of the daily rotation is expressed by $n \sin \varphi$ for the latitude φ, where n is the angular velocity of the earth's rotation. We have therefore in the above expression to substitute $n \sin \varphi$ for ω in order to find the magnitude of the centrifugal force effective in a cyclone. The term $n^2 \sin^2 \varphi$ must be omitted as before, because we refer the difference of pressure or the barometric gradient to the elliptical surface of the earth and not to the surface that would be if there were no rotation about an axis.

Let

$b - b'$ be the difference of pressure, expressed by the height of a column of mercury, for a unit of distance in the horizontal direction along the normal to an isobar upon the earth's surface or a surface parallel thereto, and let

σ be the specific gravity of mercury,

then will the pressure of the unit volume of air in the direction of the normal and toward the side of lower pressure be equal to $(b - b')\,\sigma$. The pressure in the opposite direction of the unit of volume resulting from the centrifugal force of the rotating air is, according to an elementary proposition in mechanics, expressed by

$$\frac{\delta}{g}\frac{v^2}{r} = \frac{\delta}{g} r\,\omega^2,$$

where

δ is the specific gravity of the unit volume of air,

g the acceleration of gravity,

v the linear velocity of the air in its path,

ω the angular velocity of the air in its path,

r the radius vector of the air in its path.

In our case,

$$r\,\omega^2 \text{ is } (2\,n \sin \varphi + u)\,v.$$

If, therefore, the air neither approaches nor recedes from the axis of rotation, the following equation must obtain:

$$(b - b')\,\sigma = \frac{\delta}{g}(2\,n \sin \varphi + u)\,v.$$

If further we designate by

ΔB the "gradient" or the barometric difference for a definite distance l (the London Meteorological Office assumes $l = 50$ nautical or geographical miles $= 92.76$ kilometers),

then from this definition follows

$$(b - b') = \frac{\Delta B}{l},$$

and by substitution of this value we find

$$\Delta B = \frac{l}{g} \cdot \frac{\delta}{\sigma} (2\, n \sin \varphi + u)\, v.$$

Let

B be the barometric pressure at a given place,

T the temperature expressed on the absolute scale, that is to say,

$$T = 273^\circ + t,$$

then we have

$$\delta = \frac{1}{v} = \frac{B}{760} \cdot \frac{10333}{R\,T},$$

where 10,333 kilograms is the pressure of one atmosphere.

If we substitute this value of δ, and insert the numerical values of $g = 9.806$ meters (for $\varphi = 45^\circ$), $\sigma = 13596$ kilograms, $R = 29.3$, then we find

$$\Delta B = \frac{l}{287.4} \cdot \frac{B}{T} (2\, n \sin \varphi + u)\, v. \qquad \text{(I)}$$

In this formula, l is expressed in meters, B in millimeters, $2\,n$ and u in terms of the radius, v in meters per second of mean time; $2\,n$ is a constant whose numerical value,

$$2\,n = \frac{4\,\pi}{86164} = 0.0001458,$$

we have not inserted in the formula merely for typographic reasons and convenience.

The equation (I) represents the gradient ΔB as a function of the velocity of the wind in case that the air describes a purely central movement, and has therefore no frictional resistance to overcome, as, also, that no new masses of air are drawn into the movement.

We will now illustrate the use of this formula by two numerical examples, whereby, however, it must be remarked that it is only as a first approximation that it can find an application to actual conditions. For numerical computations, our formula first acquires a more convenient form when we put $B = 760^{mm}$, and $T = 273^\circ$, or t equal to 0° Centigrade or Réaumur, which is always allowable, since the inaccuracies that result from these assumptions are smaller than those that attend the imperfect theory itself. We will put the distance l equal to one German mile, or 7.42 kilometers. Finally, if we consider that $u\,v = \frac{v^2}{r}$, where r represents the distance from the axis of rotation, then the formula becomes

$$\Delta B = 71.875 \left(0.0001458 \sin \varphi \,.\, v + \frac{v^2}{r} \right).$$

If we desire to refer the gradient ΔB (which will be given in millimeters) to the English unit of 50 nautical miles [instead of one German

mile], then must the value given by this formula be multiplied by 12.5 (or $\frac{1}{4}$°).

In the night of January 26–27, 1874, we experienced in Vienna the most violent storm (from the WNW.) since the establishment of the new anemometer. The maximum velocity of the wind attained 31 meters per second (see this Journal, vol. ix, p. 62). The mean velocity between 7 a. m. and 8 a. m. was 27.5 meters. The synoptic charts of Captain Hoffmeyer show that on this morning an area of low pressure (720 millimeters) existed in the neighborhood of St. Petersburg, and that the gradient toward this point was, in the neighborhood of Vienna, 0.22 millimeter per German mile.

If we put $\varphi = 48°$, $v = 27.5$, and $r = 1630$ kilometers, or about the distance of Vienna from St. Petersburg, then we find from the preceding formula:

ΔB resulting from the earth's rotation $= 0.214$
ΔB resulting from the centrifugal force $= 0.033$
Therefore the whole $\Delta B = 0.25$

We see clearly from this that even the imperfect theory affords a very approximate value for the barometric differences. It further follows that the influence of centrifugal force may be neglected in the storms of our latitude, which generally extend over a very great extent of surface, and in which the greatest velocity of the wind does not commonly occur in the neighborhood of the storm-center (or rather of the lowest barometric pressure). For comparison, I will add that the greatest gradients known to me directly from our telegraphic weather-reports are the following:

1869, November 14, 7 a. m.—Wind WNW., force 10 at Vienna. Gradients: from Vienna to Cracow, 0.22; Vienna to Ischl, 0.28 millimeter per German mile.

1869, December 2, 7 a. m.—Bora of hurricane force in the Gulf of Trieste and in the Adriatic: The gradient from Klagenfurt to Pola was 0.31 millimeter.

We will now consider a tropical whirlwind, and choose that which devastated the island of St. Thomas on the 21st August, 1871. The observations show that at distances of about 57 and 111 English miles from the central point of the whirlwind the pressures were respectively 10 and 17 millimeters higher than in the central calm space, whose radius was 3.6 English miles. This gives gradients of 0.86 millimeter and 0.60 millimeter for one German mile. If we substitute in the formula the numerical values $\varphi = 28°$, $v = 30$, $r = 57$ English miles $= 91.7$ kilometers, we find

ΔB as the effect of the earth's rotation $= 0.10$
ΔB as the effect of the centrifugal force $= 0.71$
ΔB the total of both influences $= 0.81$

Therefore, a wind-velocity of only 30 meters suffices to explain the observed extraordinary difference of pressure, $\Delta B = 0.73$, in a distance

of 57 miles. We further learn from this example that in whirlwinds of smaller dimensions the influence of the centrifugal force many times exceeds that of the earth's rotation, so that in these cases the latter, in low latitudes, may be neglected without great error.

Consequently, in our storms [latitude 50°] the barometric depressions are principally a consequence of the influence of the earth's rotation upon the moving masses of air; in the tropical cyclones, on the other hand, the depressions are a consequence of the centrifugal force.

Professor Loomis has endeavored to prove that the centrifugal force can produce no sensible barometric depression. (See his memoir "On Certain Storms, &c.," page 24, Smithsonian Contributions.) He computes for the storm of the 25th December, 1839, in Central Europe, that at a distance of 400 miles the centrifugal force was, in round numbers, only $\frac{1}{6000}$ part of gravity, and concludes thence, further, that therefore the pressure could, on that account, only sink about the $\frac{1}{200} = \frac{30}{6000}$ of an inch. That this conclusion is wholly erroneous need scarcely be remarked, had not the result been quoted in an excellent English handbook of meteorology.

In nature, the conditions are not so simple as we have hitherto introduced in our computations. The air does not move in a circular orbit about the storm-center, but flows toward it in spiral paths. Ferrel seeks to introduce this spiral movement, and also the frictional resistance, into his computation. We give in the following his presentation of the subject, but can, for several reasons, not consider it as correct.

When the air flows in toward the center of the cyclone (or in the upper strata flows away from it), we must in equation (I) introduce in the right-hand member another term, F, which shall represent the resistance to the movement. Similarly the entire centrifugal force of the curvilinear movement is not now active, but a less force, whose amount we find by dividing the actual velocity, ru, into two components, one in the direction of the tangent and the other perpendicular thereto.

If we indicate by i the angle between the actual direction of motion and the tangent, then will the first of these components be represented by $ru\cos i$, or $v\cos i$, and the centrifugal force depends only upon this. We have therefore, now, as a new equation for spiral movements, the following, in which the value of F remains still to be determined:

$$(I') \qquad \Delta B = \frac{l}{287.4} \cdot \frac{B}{T} \cdot \left\{ (2n\sin\varphi + u)\, v\cos i + F \right\}.$$

According to the principle of the conservation of areas in the case of purely central forces, the following equations must obtain in all parts of a cyclone:

$$r^2 (n\sin\varphi + u) = \text{Constant};$$

and therefore

$$-r\,du = 2\,(n\sin\varphi + u)\,dr.$$

The second member of this last equation is the expression of the force which would strive to preserve a rotatory motion about the center. In

case of the absence of every frictional resistance, this entire force will be applied to the acceleration or retardation of the rotatory movement of the particles of air according as these are respectively approaching to or receding from the center. When, however, any friction exists, this force will be almost exclusively used to overcome this frictional resistance. If, now, we designate this frictional resistance by F', which acts in the direction perpendicular to the radius along the portion $v \cos i$ of the path, as we have previously designated by F the resistance acting in the direction of the radius along the portion $\frac{dr}{dt}$, then the following relations hold good:

$$F' \text{ is very nearly} = 2(n \sin \varphi + u) \frac{dr}{dt};$$

$$\frac{F}{F'} = \frac{\left(\frac{dr}{dt}\right)}{v \cos i};$$

$$F = \frac{2\, n \sin \varphi + 2\, u}{v \cos i} \cdot \left(\frac{dr}{dt}\right)^2.$$

This latter expression is always positive, and attains its greatest value in the neighborhood of the earth's surface, where the frictional resistance is the greatest. With increasing altitude, where only swiftly moving air rubs against more slowly moving air, the friction rapidly diminishes, while the angle i also approximates to its limiting value of zero.

If, now, we substitute this value of F in the equation (I'), after we have previously multiplied numerator and denominator by $v \cos i$, we can, with slight error, eliminate the common factor $v \cos i\,(2\, n \sin \varphi + u)$, whereby the equation acquires the following form:

$$\Delta B = \frac{l}{287.4} \cdot \frac{B}{T} (2\, n \sin \varphi + u)\, v \cos i \left\{ 1 + \frac{\left(\frac{dr}{dt}\right)^2}{(v \cos i)^2} \right\}.$$

But since, according to the definition of i, the ratio $\frac{dr}{dt} : v \cos i = \operatorname{tang} i$, therefore the definitive expression for the gradient in the case of a spiral movement of the air is as follows:

(II) $$\Delta B = \frac{l}{287.4} \cdot \frac{B}{T} \cdot \frac{(2\, n \sin \varphi + u)\, v}{\cos i},$$

in which

$$u = \frac{v \cos i}{r}.$$

In reference to this equation (II), we must make the following remarks: First, that part of the gradient that results from the term $2\, n\, v \sin \varphi$ is really entirely independent of the angle i or of the direction of the currents of moving air, but the formula allows it to increase with increasing values of i, which must be incorrect. Secondly, the second term which repre-

sents the influence of the centrifugal force appears to be independent of i, since the development shows it to be equal to $\frac{l}{287} \cdot \frac{B}{T} \cdot \frac{v^2}{r}$ (or, as given in the second page of the original, $= \frac{P}{P'} \cdot \frac{v^2 \cos i \sec i}{8\,300\,000\,r}$, which is the same, excepting, of course, the constant), but in our storms [latitude 50°] almost the only term of influence is the first; therefore from Ferrel's formula we should find too large a value for the gradients.

In the latest number of Symon's Meteorological Magazine (March, 1875), STRACHAN has applied Ferrel's formula (II) to Toynbee's charts of the 5th February, 1870. These latter give the gradients ΔB as $= 0.114$ English inch for each 100 miles; v was estimated as equal to 56 miles per hour, and since $\varphi = 45°$, $r = 350$ miles, $i = 45°$, therefore the formula gives $\Delta B = 0.320$ which is nearly thrice too large. But if we compute according to our formula (I), and neglect the centrifugal force, as is allowable in this case, we find $\Delta B = 0.156$ inch. Had we used the formula (I'), and neglected F, it would have given $\Delta B = 0.160$ inch. Therefore, in both cases, we obtain much more correct values than according to Ferrel's formula (II).

We give now in abstract Ferrel's discussion of formula (II). We have designated by u the angular velocity of the rotating mass of air. Besides this rotation, however, in general there is also a movement either toward or from the center of the cylone; the former occurs in the lower portion, the latter in the upper portions of the cyclone. The value of i, therefore, has opposite signs above and below, and somewhere in the middle i must entirely disappear, the movement being assumed purely circular.

The value of i depends mostly upon the friction, but to a certain extent also upon the inertia of the mass of air in those cases in which the movement is increasing or diminishing, as in the beginning and ending of the cyclone. It is therefore also greatest over the land and near the earth's surface, and comparatively slight at sea, and especially so in the upper strata of the atmosphere. It further depends on the geographical latitude, and at the equator we have $i = 90°$, for there can be there no rotation, but the movements are directly toward or from the center of a region of expansion or condensation.

The greater the value of F' for the same value of r, so much the greater will be dr, and therefore also i. When for different velocities the friction increases in proportion to the velocity, then must dr increase in the same proportion (since $F' = 2\,(n \sin \varphi + u)\,dr$) and i remains constant for all velocities as long as u can be neglected in comparison with $n \sin \varphi$, that is to say, for large distances from the center. But nearer to the center of a cyclone, where u is very large in comparison with $n \sin \varphi$, dr is very small, and, under the same circumstances, therefore also the value of i. For all ordinary winds, the value of i is probably nearly constant for all velocities, and therefore observations for a given

sort of surface (land, sea, &c.) suffice to determine a value of i, which can then be applied to all cases of cyclones of every degree of severity above a surface of the same kind.

These conclusions agree very well with the results of the investigation of Clement Ley into the inclination of the wind to the isobars (see this journal, vol. ix, p. 95). The observations at the English stations gave a larger value of i in the interior of the country than on the sea-coast and in the upper regions of the atmosphere. Ley further found that the inclination was the greatest for the ESE. winds, and least for the WNW. winds, while the mean direction of progress of the cyclones was from SW. to NE. The inclination, therefore, appears greatest in the front portion of the cyclone, where masses of air previously at rest must be first set in motion, and perhaps this is a general law.* It also agrees with the theory that in the interior of a continent the strong winds should have a less inclination to the isobars than the weak ones, and that the inclination is much more constant for strong than for weak winds, for the strongest winds are to be found in the neighborhood of the center of a cyclone where $\frac{v^2}{r}$ is large in comparison with $v\,n \sin \varphi$.

Professor Loomis found the value of i in the United States under north latitude about 45° much greater than Ley found it for Great Britain under north latitude about 50°. This agrees in general with theory. The somewhat too rapid increase of i is, according to Ferrel, to be ascribed to the greater resistance due to friction in a less cultivated, wooded country.

The trade wind at a mean latitude of 20° gives an inclination $i = 20°$, which is very much greater than Ley found at coast stations in England.

In the case of violent tornadoes and waterspouts, where the rotation takes place very near to the center and with the greatest violence, u is more important than $n \sin \varphi$, and this term can be entirely neglected, especially in low latitudes. On the other hand, in extensive cyclones and at a considerable distance from the center, $n \sin \varphi$ is more important than u, and the value of ΔB depends principally upon the effect of the earth's rotation, and only in slight degree upon the centrifugal force that is called out by the rotation with reference to the earth's surface of the mass of air about the center.

In the center of a cyclone, the pressure of the air must be a minimum: therefore $\Delta B = 0$; whence also $v = 0$; and a calm must prevail at the center.

In large cyclones, up to considerable distances from the center, ΔB attains no great value, and therefore the calm region must have a considerable diameter. In many cyclones, the area of perfect calm attains a diameter of 30 miles.

In the outer portion of a cyclone, the rotation must necessarily be in

* But Loomis found the greater inclination in the rear in the American storms (see this journal, vol. ix, p. 249).

the opposite direction, and the component $v \cos i$ of the rotatory movement must be negative, and therefore ΔB will be also negative. At a certain distance from the center of a perfect cyclone, between the center and the extreme limit, the pressure will be a maximum, and $\Delta B = 0$. At this distance, $v = 0$, or calms must also prevail. Therefore an area of high pressure must, in general, be attended by calms. An easy computation shows that for the same gradients the wind-velocity must sensibly diminish toward the center. Unfortunately, the observations at hand do not suffice to test the relation between observed gradients and velocities.

The empirical law of Buys Ballot is, says Ferrel, included in the preceding expression for ΔB. This expression is, however, correct for all latitudes and inclinations of the wind to the center, where Buys Ballot's law no longer applies. With reference to the force or velocity of the wind, we perceive by a simple inspection of the formula that the velocity in all parts of a cyclone, for the same constant geographical latitude, is not alone proportional to ΔB, and, further, that in different latitudes the value of v for the same gradient is nearly inversely proportional to the sine of the latitude, especially at a considerable distance from the center. Hence, also, for the same gradients the velocity of the wind is much greater in the tropics than in higher latitudes. We may add that Toynbee (see this journal, vol. ix, p. 79, and vol. x, p. 63) had also previously called attention to this fact, and Blanford had drawn the same conclusion from the isobars for India. The form in which we have presented Ferrel's equation further shows that for equal wind-velocities the gradient diminishes also with the temperature, but to a very slight degree. The same result is furthermore brought about to a very considerable extent in the higher regions of the atmosphere by the diminishing atmospheric pressure, indeed, the barometric variations actually do diminish with the altitude, while the wind-velocities do not.

All irregular barometric variations depend almost entirely upon cyclonic action and are in general caused by the passage of a cyclone near the place of observation; hence, at the equator, where no cyclone can be formed, the irregular barometric variations are scarcely sensible. On this point, Ferrel quotes the same evidence from Sykes and Humboldt, as given in Herschel's Meteorology, that we have ourselves reprinted on page 12, volume x, of this journal. At the equator, no cyclone can arise; and therefore in storms the movement of the air at the earth's surface is directly toward the center of the area of diminished density of the atmosphere, and the inertia of the air, as well as the friction, both overcome by the force that results from an almost imperceptible gradient. Hence, Ferrel also considers that his neglect of the inertia in the deduction of his formula for the gradient can in any case only give rise to a very slight error. In a cyclone, the force that results from the gradient is almost entirely held in equilibrium by the centrifugal force that arises in consequence of the rotatory motion and the earth's diurnal rotation, and so great is the mobility of the air and so slight the

influence of friction that only a very small part of that force (due to the gradient) is applied to the preservation of the movement of the air between the inner and outer portions of the cyclone.

If the friction is proportional to the first power of the velocity, then it results from the equation for F^v, that the rotatory movement of the cyclone, and consequently the value of v, is proportional to the sine of the latitude, whence the entire difference in pressure between the inner and any definite exterior portions of the cyclones, or $\Sigma \Delta B$, must be proportional to the square of sin φ. Therefore, the mean monthly range of the barometer must increase with the latitude, and nearly in the ratio of $\sin^2 \varphi$. This also corresponds very well with observation. If we put the mean monthly range at the poles at $1.6^{\text{inch}} = 41^{\text{mm}}$, we obtain the following comparison of the observed values (according to Loomis's Meteorology) and the computed values:

$\varphi =$	0°	30°	45°	65°	78°
Computed range	0mm	10mm	20mm	33mm	35mm
Observed range	3	10	25	34	31

A more complete agreement is not to be expected, since other matters come into consideration besides the influence of latitude. The violence of the rotation in a cyclone, and consequently also the extent of the central barometric depression, depends to a very large extent upon the amount of aqueous vapor that is conveyed into the cyclone, and this diminishes from the equator toward the poles. On the other hand, the great cyclones that advance from the lower to the higher latitudes increase steadily in diameter, and hence the amount of depression at the center and the amount of the barometric oscillation at any one place are always greater as we approach the Poles. These two effects mutually enfeeble each other to a certain extent. In the slight variation of 3 millimeters at the equator is included the diurnal period, which has exactly this amount. In fact, after eliminating this diurnal period, the irregular variation becomes equal to zero, corresponding to the theory. We have here a complete explanation, which has hitherto been wanting, of the [irregular] barometric variations, and their dependence upon geographical latitude.

These are the most important consequences in reference to cyclones that Ferrel (Amer. Jour. Sci., Nov., 1874), in his above mentioned memoir, deduces from his formula for the gradient. He, however, further applies the same equation to explain also the general distribution of atmospheric pressure under different latitudes on the earth's surface. Wherever in the atmosphere, from any cause whatever, a rotatory motion is set up over a large portion of the earth's surface, this motion furnishes a value of u and of v in the expression previously given for ΔB. The term that depends upon u is, in such a case, very small in comparison with that which depends upon $2\,n \sin \varphi$, and can be neglected. Equally can i be put $= 0$, and therefore, also, v be put $= r\,u$. A positive v cor-

responds to a rotation from right to left in the northern hemisphere, but the contrary in the southern hemisphere. In our hemisphere, v, and therefore ΔB, will be negative for a motion from left to right; that is to say, a higher pressure prevails in the center. Ferrel now explains by his formula the diminution of atmospheric pressure toward the poles, in that he treats the prevailing easterly movement of the air outside of the tropics as "polar cyclones." In a similar manner originates the low pressure at the equator and the high pressure in the neighborhood of the tropics between the two great cyclonic movements of the atmosphere.

We refer those of our readers who are further interested in this part of Ferrel's deductions, besides the memoir just reviewed, especially to the memoir in the number for January, 1861, of Silliman's American Journal, 2d series, vol. xxxi, entitled "The Motions of Fluids and Solids Relative to the Earth's Surface." We find therein a complete theory of a new, somewhat complicated, system of atmospheric circulation.*

From this latter, earlier memoir of Ferrel's, we will here quote some additional paragraphs having reference to storms, because they present his views in reference to the origin of storms, which are scarcely to be inferred from the memoir just reviewed. In the third chapter, "The Motions of the Atmosphere arising from Local Disturbances," are found the following remarks:

Excess of heat or increased amount of aqueous vapor is the first cause of the ascent of air and the influx from all sides. The inflowing air ascends, condenses its aqueous vapor, whereby its ascensional power is further increased, and from this cause the disturbance can continue for some time. For reasons previously given, this process can, in the equatorial regions, give rise at the most to tornadoes only, and in fact Reid's charts show no cyclone traced back to 10° latitude, no typhoon traced beyond 9°. The greater expansion of the air in consequence of higher temperature and greater quantity of vapor must without doubt exert an influence upon the barometric pressure. Notwithstanding this, that theory is untenable which ascribes all barometric variations to the condensation of cyclonic vapor, for according to it the variations of atmospheric pressure would be greatest at the equator. The atmosphere is exceedingly mobile. Every disturbance of equilibrium will be quickly restored by an inflow of air, provided no whirl arises. If, therefore, the earth had no rotation about an axis, then would the non-periodical

* Our author has apparently not had access to the more important and earlier memoir of Ferrel "On the Motions of Fluids and Solids, &c.," in "Runkle's Mathematical Monthly," volumes i, ii, and iii; Cambridge and New York; 1857 to 1859. These volumes, although rare in Europe, are, however, still easily obtained by American students from Sever & Francis, of Cambridge, Mass., and should be consulted. Copies of a subsequent separate reprint of this fundamental memoir were published by Ferrel in 1860. The memoirs referred to by Hann in Silliman's Journal are to be considered as elementary expositions of the rigorous equations published in the Mathematical Monthly.—NOTE ADDED BY THE TRANSLATOR.

barometric variations nowhere be greater than they at present are at the equator.

When the disturbance of equilibrium is large, but only extends over a small area, then is the centrifugal force greater than in the case of extended cyclones. The rotations are then very rapid and close to the center, as in tornadoes. These occur at times of great heat and calms, whereby the equilibrium in vertical direction is disturbed. The lower strata rise upward, a rapid inflow takes place from all sides; and when the sum of all the initial moments of rotation is not equal to zero, which will seldom be the case, then must the mass of air near the center execute rapid rotations, and a tornado is the result. We can well represent this by the flow of water out of a basin through a hole in the bottom. When, at the beginning of the motion, the fluid is in perfect rest, the efflux takes place without rotation; but when the slightest initial rotation is present, then the outflow is accompanied by rapid rotations.

In tornadoes, which are always of small dimensions, the influence of the earth's rotation upon the production of rotation is very slight in comparison with the influence of the initial condition of the atmosphere. Therefore the direction of the rotatory movement in a tornado is sometimes from right to left, sometimes the reverse. Therefore at the equator tornadoes can occur, but no great cyclones. In these latter, the initial condition of the atmosphere is of little consequence in comparison to the influence of the earth's rotation, and this latter is constant, while the former is easily nullified by resistances. Therefore the great cyclones have a long existence, while the tornadoes, depending principally on the initial intensity of their rotation, are soon brought to rest by the resistances.

In consequence of the great centrifugal force near the center of a tornado, caused by the rapid rotation, almost a vacuum must exist there. When, therefore, a tornado passes over a building, the exterior pressure is suddenly removed, and the air within presses with nearly 10,333 kilograms per square meter; hence is produced a destruction as if by an explosion.

The progressive motion of cyclones can be explained by the inequality of the centrifugal forces on the polar and equatorial sides of a cyclone. The term of the gradient depending on $2\,n \sin \varphi$ is greater on the polar than on the equatorial side, while the other moments remain the same. The cyclone, therefore, moves toward the direction of the greater diminution of pressure or toward higher latitudes. It is therefore not necessary to assume that a real transfer takes place from the equator to the pole of the mass of air that forms the cyclone. The deviating force and the motions are greater on the polar side of the cyclone, and on this side new portions of the atmosphere are continually drawn into the movement, since on this side $n \sin \varphi$ is increasing steadily, while on the equatorial side the motion ceases by reason of the frictional resistance and the inertia of the air. Thus the center of the cyclone is continually being formed anew during the progress toward higher latitudes.

At the same time, the cyclones in the region of the trade winds follow the general movement of the atmosphere in these latitudes from east to west, and similarly in the extropical region they move from west to east. From the resultants of the two constant forces, the polar tendency of the cyclones and the influence of the prevailing movement of the atmosphere, there result the parabolic paths of the cyclones or their recurving when they pass from the trade winds into the region of the west winds.

Thus far FERREL.

The influence that a prevailing general current of air exerts upon the progress of a whirlwind that has entered into it evidently consists in this, that the masses of air drawn into the whirlwind have to follow two impulses: one, that which is due to the whirl; and the other, that which is due to their original movements. Therefore, in the region of trade winds and on the northwest side of a whirl, the motions are most accelerated, but on the opposite side are most retarded, and thereby the whirl must receive a tendency to progress toward the northwest. I believe that in its principal feature this agrees also with LOMMEL'S theory of the recurving of the paths of cyclones on their leaving the trade-wind region (see this journal, vol. ix, p. 270). The expression, "Stauung der Luft" *stowing away* or *damming up* or *banking up* of the atmosphere, seems to me also not well chosen. I say also, for one of the most competent authorities in the study of the theory of storms writes me in reference to Lommel's views as follows: "I cannot understand this theory. The northeast trade does not blow when the cyclone wind prevails. Therefore they cannot bank each other up. It would, however, be interesting to know whether the tropical cyclones have not always a maximum of temperature or aqueous vapor on their right-hand or northeast side. This is an anomaly in the distribution of these elements in the tropical regions, but the cyclones, also, are infrequent phenomena."

It would certainly be of the highest interest to know the distribution of temperature in the trade-wind region during a cyclone, for this would afford an important test of our storm theories. I believe, however, that the author of the preceding quotation will find fewer difficulties in my presentation of the influence of a general atmospheric current upon a cyclone entering therein. I do not think that everything is explained by this and by FERREL'S "polar tendency," but certainly both views ought to be taken into consideration.

[NOTE BY THE TRANSLATOR.—Having, in 1865–'66, had occasion to personally explain the views of Mr. Ferrel to several astronomers and meteorologists in Europe, and having, in 1869–'70, delivered popular expositions of the same subject in connection with the publication of the Daily Weather Bulletin and Forecasts of the Cincinnati Observatory, the author was peculiarly gratified to be able to present these views to a still larger circle by the publication, in May, 1871, of his notes on the use of the tri-daily weather maps of the Signal Service, and would refer American students to the "Monthly Weather Reviews" and other publications of that office for innumerable illustrations of the application of Ferrel's theory. See also the recent publications of Loomis and Ferrel.—C. A.]

H.

REPLY BY MR. FERREL TO THE CRITICISMS OF MR. HANN.

[Zeit. Oest. Met. Gesell., x, p. 254, August, 1875.]

In the presentation of Ferrel's formula (vol. x, Nos. 6 and 7) we have made certain objections to his method of introducing the friction therein, to which Mr. Ferrel replies from Washington as follows, in a letter of the 27th April:

"The resistance of the earth's surface to the rotatory movement of a cyclone can only be overcome by the force that according to the principle of the conservation of areas results as soon as the air is constantly drawn by a centripetal force toward a center. If at a distance of 400 miles from the center of a cyclone the air has no rotatory movement relative to the earth's surface, nevertheless, it still has a rotatory movement about the center of the cyclone in consequence of the earth's rotation, the expression for which is $r\,n \sin \varphi$; or, at the parallel of 45°, a linear velocity of about 74 miles per hour. Were there no friction, then would the air when it arrives at a distance of 100 miles from the center have a rotatory movement of $4 \times 74 = 296$ miles; and if we now subtract the rotatory motion in this distance due to the earth's rotation, that is to say, 15.8 miles, we obtain 277.5 miles for the velocity of rotation relative to the earth's surface, and perpendicular to the radius. The force which overcomes the inertia and produces this motion is expressed by

$$r \frac{du}{dt} = \frac{du}{dt} \cos i.$$

Now, in the case of friction, we have, instead of a rotatory movement of 277.5, one, say, of 40 miles; so that in this case over $\frac{7}{8}$ of this force is lost in overcoming the friction, and this gives an approximate measure of the amount of the frictional resistances.

"The inertia, like the friction, opposes the force due to the centripetal movement; therefore, its expression is

$$F' = -r \frac{du}{dt},$$

and we thus obtain the expression for F' as it is given at the bottom of p. 99, vol. x.* It must certainly be considered, however, that this is only an approximate presentation of the frictional resistance, including the inertia of the fluid, in case there occur changes in its velocity; but this latter is in general only a very small part of the total resistance to movement.

"As the two components of the friction in the direction of the tangent and of the radius, we now have

$$F' : F = \frac{dr}{dt} : v \cos i,$$

and this gives F, as at the bottom of p. 99, vol. x,* as an approximate expression for the effect of friction in the direction of radius. In order

* See page 62.

that these components may be overcome, there is necessitated an increase in the gradient, and therefore, ΔB increases. Substituting the expression for F, gives the definitive formula for ΔB as it is presented on p. 100, vol. x, and which therefore must be nearly correct, since the whole effect of the friction upon the ratio between gradient and velocity is, in general, not very large, and therefore a part of it can have only a very slight influence.

"In the case of spiral movement, ΔB diminishes in the ratio of unity to cos i; but since the expression for F, as we have deduced it, increases in the ratio of $\cos^2 i$ to unity, therefore ΔB will, in consequence of the friction, increase more than it diminishes, and therefore cos i appears in the denominator of equation II.

"ΔB will only be independent of i in case that we can show that the true value of F is a function such that, being substituted in equation II, it causes ΔB to increase precisely in the same ratio in which cos i diminishes.

"The formula cannot be rigidly tested by comparison with special cases. For the determination of the gradient we can only use observations at distant places, which do not allow the consideration of the influence of numerous local disturbances of slight extent. However, I quote here certain relations between the gradients and wind velocities from Professor Loomis, in American Journal of Science, January, 1875. Each of these numbers represents the mean of a considerable number of observations. The velocity of the wind is given in English miles per hour; the gradient in English inches of the barometer per 100 miles of distance:

Wind-velocity observed	10	15	20	25	30	35
Gradient observed	.086	.096	.105	.105	.124	.152
Gradient computed	.043	.067	.092	.118	.146	.175

"The mean inclination of the wind-direction to the radius is assumed at 45°, the mean distance from the center of the cyclone at 350 miles, and the mean geographical latitude at 45°. We see that the observed gradients, in a slightly regular manner, increase with the velocity of the wind, because the influence of abnormal disturbances and of other causes are not completely eliminated. We further see that for a velocity of 22 miles the theory agrees with observation. For lower velocities the theoretical gradient is too small; for larger velocities it is too large. But in the computation we have assumed that i is constant for all velocities. If we assume that for velocities between 10 and 35 miles the value of i is respectively 60° and 35°, then the computed and observed values agree within the limit of the probable errors of the latter. This, however, gives a mean value of i that is greater than 45°. The theory cannot be rigidly tested until, by means of observations, the connection between the wind-velocity and the angle i is established. If we put $\cos i = 1$, and thus make the gradient ΔB independent of the angle i, then will all computed values of the gradients be too small."

I.

SOME REMARKS CONCERNING THE NATURE OF CURRENTS OF AIR.

By A. Colding.

[Translated by Cleveland Abbe and H. L. Thomas, from the Oversigt over det K. Danske Videnskabernes Selskabs Aaret 1871, page 89, with occasional reference to Hann in Zeitschrift Oest. Met. Ges., vol. x.]

These remarks are based mainly upon the results of certain investigations into the movement of water in currents* which I had the honor

* [Note by the Translator, February, 1878.—The article G of the present collection gives some idea of the results of Ferrel's dynamical theory of the winds and currents on a rotating globe, but as the writings of Colding, Peslin, and others have considerable merit as being the best that can be done with the purely kinematic theory, the translator takes pleasure in also presenting their memoirs to American students, and as a corrective to these would refer to Mr. Ferrel's criticisms in "Nature" for 1871 and 1872, as well as his memoirs of 1856, 1859, and 1877.

The general problem of movement on the earth's surface was treated of in an imperfect way by numerous authors from Hadley and Newton to Laplace and Poisson. The latter in 1837, in his memoir on the movements of projectiles, among other things, mentioned the deviation of the projectile to the right produced by the rotation of the earth, but appears to have overlooked its importance as a dynamic law and to have derived it from geometrical or kinetic principles.

In 1832, Professor Johnson published, in the American Journal of Science, a memoir upon his rotascope. In 1851, Foucault presented to the Academy of Sciences of Paris his famous pendulum experiments, and subsequently his gyroscope. Both these authors explained the phenomena in question on purely kinetic principles, or on the presumed law that a rotating body tends to preserve its axis of rotation. Hereupon followed a long discussion in the Paris Academy (fully reported in the Comptes Rendus, tome xxxii–li, 1851–1860), in which many eminent men took part. Poinsot and others would explain the phenomena by the purely geometrical laws of the composition of rotations; but the dynamics of the problem were exposed by Birnet, C. R., 1851, xxxii, pp. 157 and 197; by Babinet, C. R., 1859, xlix, pp. 638, 686, and 769; Delaunay, C. R., 1859, xli, p. 688; and Poncelet, C. R., 1860, li, pp. 467 and 511.

Meanwhile the gyroscope also was exciting renewed attention in the United States, and an original and satisfactory investigation of its phenomena (the first that I know of based on correct general dynamical principles) was published by Ferrel in 1856 in the "Nashville Journal of Medicine and Surgery," vol. xi (see also in "Gould's Astron. Jour." and in "Runkle's Math. Monthly"). Of other investigations I note only one (kinetic and not dynamic), by General J. G. Barnard, in Am. Jour. Sci. (several papers from 1855 to 1859), see also his "Problems of Rotary Motion" in the Smithsonian Contributions, xix, and his article "Gyroscope" (where fundamental principles are introduced) in Johnson's Cyclopædia, N. Y., 1877; also, Snell on the "Rotascope" in Ann. Rep. Secretary of the Smithsonian Inst., 1855.

Mr. Ferrel's paper on the gyroscope was immediately preceded by his first essay (1856) on the winds and oceanic currents, an elementary paper published in the same volume of the Nashville Journal. His more elaborate mathematical memoir was finished in 1858, and published during 1859 and 1860, as "The Motions of Fluids and Solids Relative to the Earth's Surface," in the Mathematical Monthly; separate copies, with a few additional words, were struck off in 1860. This memoir of 72 pages has been further elaborated into "Meteorological Researches, Part I," published by the United

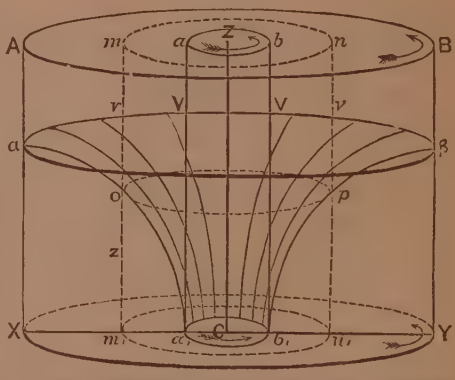
to lay before the society in the year 1869, and which may now be found among the memoirs published by the Danish Society, 5th series, vol. 9, part III. In that dissertation I showed that if a current of water moves on a cylindrical surface perpendicular to its rectilinear elements, the current of water having the depth H, and the surface of the current moving with the velocity V, then the velocity of the current at the depth x, beneath the free surface of the water, may be represented by

$$(1) \qquad v = V\left(1 - 0.433\left(\frac{x}{H}\right)^{\frac{3}{2}}\right)$$

when the resistance to the motion of the water is of the same magnitude as that which would be offered by an underlying mass of water to the current running above.

In the present case, we will assume the cylindrical surface in question to be a vertical surface of revolution, A X Y B, Fig. 1, within which the current of water moves in the direction indicated by the arrows. Let C Z be the axis of the cylinder, and $a\,a_1\,b_1\,b$ be the free surface of the current, which is at the distance $a\,Z = a_1\,C = a$ from the axis, and at the distance $A\,a = X\,a_1 = H$ from the exterior surface A X Y B, upon which the current rotates. If it is now assumed that the free surface $a\,a_1\,b_1\,b$ rotates with the velocity V about the axis C Z, then any element of the current which is at the distance $m\,Z = m_1\,C = r$ from the axis, and at the distance $m\,a = m_1\,a_1 = x$ from the free surface of the current, as I have previously shown, will move with the velocity v, as determined by formula (1), when the rotating current is surrounded by an exterior mass of water which resists the rotation. It can then be further shown that within this rotating volume of water there is a funnel-shaped surface $a\,a_1\,b_1\,\beta$, bounded within by the inner cylindrical surface $a\,a_1\,b_1\,b$, and without by the outer cylindrical surface A X Y B, in which the pressure at all points is equal; but, beside this level surface, there is an endless number of other level surfaces in the fluid, both above and below the surface $a\,a_1\,b_1\,\beta$. All these surfaces are, meantime, so situ-

FIG. 1.



States Coast Survey, 1877. For other papers on this subject by the same author see Am. Jour. Sci., 1861, 1874; Nature, 1871, iv, p. 226; 1872, v, p. 384; 1872, vi, p. 432. Of additional recent literature relating to motions upon the earth we will only mention Hansen, Theorie der Pendelbewegung, 1856; E. Thomson, Rep. B. A. A. S., 1857; D. Vaughan, Rep. B. A. A. S., 1859; Everett, L. D. E. Phil. Mag., 1871; also in his translation of Deschanel's Philosophy; Colding, Danske Vid. Skab., 1863, 1871; Nature, 1871, v, pp. 71, 91, and 112; Schmidt, Vienna Mitt. Geog. Gesell., 1877; Finger, Vienna Monatshefte, 1877; Guldberg and Mohn, Études sur les Mouvemens de l'Atmosphère, Christiania, 1876; Zeit. Oest. Met. Gesell., 1876, 1877.

ated that, by moving from the level surface $\alpha\, a_1\, b_1\, \beta$ upward parallel with the axis of rotation C Z, we intersect the entire series of level surfaces which is formed in the rotating volume. For each of these level surfaces, the pressure upon a unit of surface is constant; but when we go from one level surface to the next, the pressure diminishes as we go upward, while it increases as we go downward toward the ground plane XY.

In order to prove the correctness of this statement, we will consider an element of the rotating fluid, which is at the distance r from the axis of rotation, and which moves with a velocity of v. If we consider the direction C Z as positive, we shall, as is well known, have, since p indicates the pressure upon a unit of surface for the element in question,

$$dp = \rho\left(-g\,dz + \frac{v}{r}dr\right),$$

where ρ indicates the density of the fluid and g the force of gravity. For each of the level surfaces of the fluid, the pressure p is constant, and $dp = 0$, therefore

$$g\,dz = \frac{v^2}{r}\,dr, \qquad \text{or} \qquad \frac{dz}{dr} = \frac{v^2}{g\,.\,r} \tag{2}$$

independently of the density ρ. From this equation, together with equation (1), are deduced, directly, the above-stated propositions concerning the level surfaces of the rotating volume of water. If the expression for the current's velocity v, as given by equation (1), is substituted in equation (2), and this equation is then integrated by making $r = \alpha + x$, and, for the sake of brevity,

$$X = \left[1 - 0.188\left(\frac{\alpha}{H}\right)^3\right]\text{nat log}\left(1 + \frac{x}{\alpha}\right)$$
$$- 1.732\left(\frac{\alpha}{H}\right)^{\frac{3}{2}} tg^{-1}\sqrt{\frac{x}{\alpha}} + 0.577\sqrt{\frac{x}{H}}\left(3\,\frac{\alpha}{H} - \frac{x}{H}\right)$$
$$+ 0.0625\,\frac{x}{H}\left[\left(\frac{x}{H}\right)^2 - \frac{3}{2}\,\frac{\alpha}{H}\,\frac{x}{H} + 3\left(\frac{\alpha}{H}\right)^2\right],$$

we obtain

$$z = z_0 + \frac{V^2}{g}\,.\,X, \tag{3}$$

in which the arbitrary constant z_0 represents the value of z for $x = 0$, so that formula (3) is the equation for any plane surface in the rotating fluid.*

If we now consider formula (1), which is applicable to water, together with formula (3), which is based upon the same, while formula (2) is of general application, we shall see that in a rotating volume of water the velocity of the rotation increases from the exterior surface of such vol-

* NOTE BY THE TRANSLATOR.—The above formulæ neglect the influence of the rotation of the earth, and are therefore applicable strictly only to tornadoes and small cyclones, or to cyclones within the tropics.—C. A.

ume toward the center, but ceases just at the inner cylindrical surface (since the velocity becomes imaginary) for all values of $r < a$, to which, also, according to (3), correspond only imaginary level surfaces. By passing crosswise through such a rotating volume, one therefore meets, as is easily seen, with conditions which harmonize with what is known concerning hurricanes in the tropics, since the velocity of rotation in the hurricane increases from the exterior inward toward the axis up to a certain distance a from the same, where the hurricane reaches its greatest violence, but beyond which even the most violent hurricane is thereafter suddenly succeeded by an absolute calm, which continues until one has passed to an equally great distance a beyond the axis. At the instant when that distance is passed, the hurricane recommences with the same violence as at the moment preceding its cessation, but from the opposite quarter, and from this time forth the force of the hurricane decreases in the same ratio as it had previously increased. But in another respect also a remarkable agreement is found between the rotating volumes of water under consideration and the rotating volume of air in a hurricane. It appears, namely, from formula (3) that since the pressure upon a unit of surface of each level surface is equal at all its points, and the pressure upon every point of the surface $a_1 a_1 b_1 \beta$, for which $z_0 = 0$, is equal to the pressure at $a_1 b_1$ in the ground plane XY, therefore the pressure must increase as we move over the ground plane XY from the surface $a_1 b_1$ toward the exterior surface XY of the rotating volume. If we are at the arbitrary distance $C m_1 = r$ from the axis CZ, we have above us, beside the pressure at the point a_1, the pressure of a column of water of the height $m_1 o = z$, and it is therefore evident that the excess of pressure at the distance $r = a + x$ from the axis above the pressure in the calm space in the center of the rotating volume is expressed by the weight of a column of water of the height z, as determined by formula (3).

As now it is known, from the observations which have been made during the prevalence of hurricanes, that conditions are met with in these rotating masses of air which correspond exactly to those which I have pointed out in rotating masses of water, and as, moreover, I have shown in a former paper, which will be found at page 1 of the Selskabets Oversigter for Aaret 1865, that the laws of the movements of aëriform bodies may be said, within the limit of accuracy with which the experiments on the movements of fluids have hitherto been made, to be identical with the laws which govern the movements of liquids, if only the diminution of pressure that occurs is represented by a column of the fluid under consideration;—I, therefore, believe that there is ground for the assumption that formula (1) will hold good not only for water, but also for the movement of gases when the rotating mass is surrounded by an exterior mass of air which resists its rotation. Experience must decide whether I am right or not in basing my theory upon this hypothesis. For the purpose of examining at once how far this theory of atmos-

pheric whirlwinds harmonizes with nature, I will compare its results with the phenomena that were observed at St. Thomas, August 2, 1837, when the so-called Antigua hurricane, which is described by Professor Dove in Poggendorff's Annalen der Physik, vol. 52, passed over the island, causing fearful havoc both there and on the island of Porto Rico, which is situated at a distance of 20 Danish miles* from St. Thomas.

The phenomena observed as prevailing during the hurricane were, according to Professor Dove, as follows:

1837.	St. Thomas.			1837.	Porto Rico.	
Time.	Barometric pressure.	Direction of wind.		Time.	Barometric pressure.	Direction of wind.
h. m.	*Lines.*			*h. m.*	*Lines.*	
August 1 18 00	337	NW.	Increasing storm			
August 2 2 10	335	N.	do			
3 20	334	N.	do			
3 45	334	N.	do			
4 45	332	NE.	do			
5 40	331. 5	NE.				
5 45	330	NW.	Hurricane			
6 30	328	NW.	do			
6 35	325. 5	NW.	do			
6 45	324	NW.	do			
7 00	324	NW.	do			
7 10	322	NW.	do			
7 22	318. 5	NW.	do			
7 30	317	NW.	do			
7 35	316. 5		Dead calm			
7 52	316		do	8 00	333. 28	NNE.
8 10	316		do			
8 20	316		do			
8 23	320	SSE.	Hurricane			
8 33	321	SE.	do			
8 38	322	SE.	do			
8 45	323	SE.	do			
8 50	324	SE.	do			
9 00	326	SE.	do	9 00	332. 16	
9 10	328	SE.	do			
9 25	329	SE.	do			
9 35	330	SE.	do			
9 50	331	SE.	do	10 00	331. 03	
10 10	332	SE.	do			
10 35	333	SE.	do			
11 10	333. 25	SE.	do	11 00	329. 9	E.
11 30	333. 5	SE.	do	12 00	315. 27	(*)
14 45	335	SE.		15 30	325. 43	S.
20 00	336. 5	SW.		16 00	332. 16	
21 00	336. 75	E.				

*Hurricane.

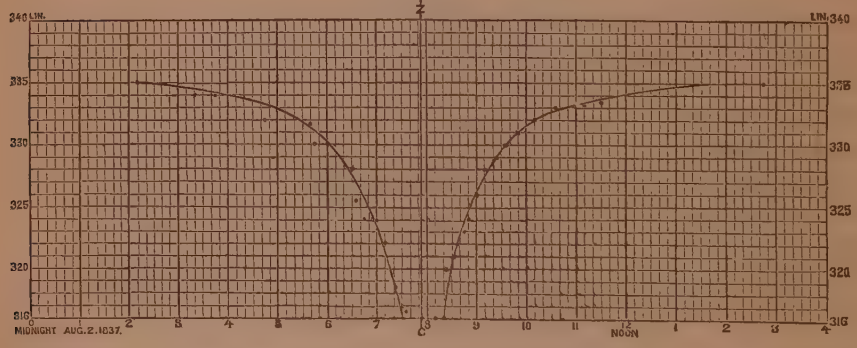
In view of the above data, we may consider that the hurricane raged from the northwest until the calm space reached the island, and that it again suddenly burst forth from the southeast after its center had passed St. Thomas. The progressive movement of the hurricane, which, from general experience, we may consider as having been uniform during the time of its passage over the island, may therefore be assumed to have been in a west-southwesterly direction toward Porto Rico. If we now observe that in such a rotating mass the pressure of the air must be considered as equal at all points that are equidistant from the axis of

* The Danish mile is equal to about 4½ English miles.

rotation, and if we next observe that at the time when the center of the hurricane passed over St. Thomas, at about 8 o'clock, the pressure of the air there was 316 lines, while at Porto Rico it was 333.3 lines, we shall see that, at a distance of 20 (Danish) miles from the axis of the hurricane, the pressure of the air was 17.3 lines greater than at the center. But if we further consider the foregoing table of air-pressures, it will be seen that, while the hurricane was approaching St. Thomas, the pressure of the air *there* was, at 4.15 a. m., equal to the pressure at Porto Rico at 8 o'clock, and that this pressure of the air was again reached at St. Thomas at 11 a. m., when the hurricane was leaving the island. In the course of $6\frac{2}{3}$ hours (from 4.15 until 11 o'clock) the hurricane moved about 40 miles (Danish). Its velocity was, therefore, about 6 miles per hour, and this agrees, in a measure, with an observation made on the island of Porto Rico at 12 o'clock, according to which the center of the hurricane seems to have traversed a distance of 20 miles in about four hours.

In the annexed Figure 2, I have, according to the foregoing table of

FIG. 2.



atmospheric pressures, observed on the island of St. Thomas during the hurricane, represented the time of observation, expressed in hours, as the abscissa, and the observed pressure of the air, indicated by the height of the mercury, expressed in lines, as the ordinate to a curve, corresponding to the pressures of the air prevailing during the hurricane. By the aid of the points thus designated, I have subsequently drawn the two branches of the curve as given, which, judging from the entire series of observations, may be considered as corresponding to the pressures of the air which were really exerted during the hurricane; and since I have commenced with the lowest pressure (316 lines) that was exerted while the center of the hurricane was passing over St. Thomas, it is evident that the curve thus constructed may be compared with the previously mentioned curve $\alpha\, a_1\, b_1\, \beta$, fig. 1, the equation of which, with rectangular co-ordinates, is:

$$z = \frac{V^2}{g} . X. \qquad (4)$$

As we have seen that the progress of the hurricane may be computed to have been equal to six miles per hour, I have divided the hour into six parts; each of these parts, therefore, corresponds to a length = 1 mile, and the given curve may thus be considered as representing the atmospheric pressure across the entire mass of air composing the hurricane. With reference to the curved line thus constructed, I will remark that the curve everywhere lies within the limits of the probable error, since it is expressly stated in Professor Dove's description that the barometer was in such a state of agitation that the mercury, at every violent gust, suddenly fell two lines, but rose immediately afterward to its usual height.

The first thing that we now perceive, when we cast a glance at the two branches of the given curve, is that these may be considered as symmetrical curves with reference to the vertical line C Z, which passed over St. Thomas at $7^h\ 52^m$; and this symmetry therefore authorizes us to consider the line C Z as the axis around which the rotation took place. In view of this, we may assume that the radius of the circumscribing cylinder of the calm space in the middle of the hurricane was $\alpha = 0.4$ hours = 2.4 miles. And if we next suppose that the rotating mass proper extended over the entire space, in which the pressure decreased proportionately inward toward the center, and especially that the rotating mass reached outward to the point where the pressure of the air was only two lines less than the normal pressure (336‴), we may make the radius of the exterior circumscribing surface of the rotating mass $(\alpha + H) = 4.4$ hours = 26.4 miles; and, as a consequence thereof, the thickness H of the rotating mass = 24 miles. During the prevalence of the Antigua hurricane, the radius, therefore, of the space where there was no wind was $\alpha = 0.1\,H$. And since the radius of any element of the rotating mass is designated by $r = \alpha + x$, it will further be easy, according to the constructed curve, to determine the amount of pressure that was exerted at the places in the hurricane which correspond to values of x equal successively to

$$0.1\,H;\ 0.2\,H;\ 0.3\,H;\ 0.4\,H;\ 0.5\,H;\ 0.75\,H;\ \text{and}\ H.$$

By seeking in the figure the corresponding pressures given by the curve for the increasing hurricane, we find the heights

$$z = 6.0;\ = 10.3;\ = 13.0;\ = 14.8;\ = 16.0;\ = 17.5;\ = 18.4\ \text{Paris lines.}$$

And by looking for these pressures in the curve of the abating hurricane, we find

$$z = 6.6;\ = 10.6;\ = 13.4;\ = 15.2;\ = 16.2;\ = 17.5;\ = 18.2\ \text{Paris lines,}$$

from which are obtained, as mean numbers,

$$z = 6.3;\ = 10.4;\ = 13.2;\ = 15.0;\ = 16.1;\ = 17.5;\ = 18.3\ \text{Paris lines.}$$

If we now consider the formula (4), in which X has the value determined by the formula (3), which value is seen to be a real number, we

may, in like manner, easily compute the pressure z, corresponding to the above given values of x and a. Computing the value of z, we get,

$$z = 0.65\frac{V^2}{g}; \quad = 1.06\frac{V^2}{g}; \quad = 1.33\frac{V^2}{g}; \quad = 1.51\frac{V^2}{g};$$

$$= 1.64\frac{V^2}{g}; \quad = 1.83\frac{V^2}{g}; \quad = 1.91\frac{V^2}{g}.$$

If we now institute a comparison between the computed and the observed values of z, it becomes evident that the computed values stand in a constant ratio to the observed values, as would be the case if the theory which has been advanced concerning atmospheric whirlwinds is correct. If we therefore make the computed values of z equal to the corresponding observed pressures z, we get several equations, which may serve to determine the constant $\left(\frac{V^2}{g}\right)$, and thus we obtain, as a mean number: $\frac{V^2}{g} = 9.76$ Paris lines. If this mean value is substituted in the formula (4) for $\frac{V^2}{g}$, it is easy to compute the pressures which correspond to the distances

$x = 0$; $x = 0.1\,H$; $= 0.2\,H$; $0.3\,H$; $0.4\,H$; $= 0.5\,H$; $= 0.75\,H$; $= 1.0\,H$.

These computed pressures are thus found to be:

$z = 0$; $= 6.34$; $= 10.35$; $= 12.98$; $= 14.74$; $= 16.01$; $= 17.86$; $= 18.64$;

while the above observations gave

$z = 0$; $= 6.3$; $= 10.4$; $= 13.2$; $= 15.0$; $= 16.1$; $= 17.5$; $= 18.3$; Paris lines.

So complete an agreement is therefore seen between the observed and the computed pressures at every place in the hurricane that we may draw the conclusion that the formula (4) is correct, and that the correctness of the theory is confirmed by nature. But if the theory is correct, and we therefore, for the hurricane now under consideration, have the pressure $\frac{V^2}{g} = 9.76$ Paris lines $= 22.0$ millimeters of mercury $= 710$ feet of air, it then further follows that the greatest velocity of the hurricane was: $V = 149$ feet (47.6 meters) per second, or something near to the greatest hurricane velocity of which we have any knowledge, which also agrees with the violence with which the Antigua hurricane raged.

We are now further able to determine the limits of the hurricane proper, a term which is usually considered to apply to winds that have velocity of 120 to 150 or more feet per second; for if in formula (1) we make $v = 120$ feet, and $V = 149$ feet, we find the required distance $x = 0.53\,H = 12.7$ miles. The hurricane proper began, therefore, at about half past five o'clock at a distance of about fifteen miles from the axis, and ceased at half past ten o'clock, or two and one half hours after the

axis of the hurricane had passed St. Thomas. In Professor Dove's paper, the statement is made that the hurricane began at $5\frac{3}{4}$ o'clock and ceased at $11\frac{1}{2}$, which statement, however, is supposed to have been made only by estimate; at all events, experience in this matter seems to correspond pretty well with what is obtained by computation. If, in conclusion, we seek the velocity with which the outer portion of the mass rotated, we find, according to formula (1), by therein making $x = H$, that the required velocity was 84.5 feet = 27.4 meters per second, or 12.6 miles per hour. If this velocity is compared with the progressive velocity of the hurricane, which we have found to be about 6 miles per hour, it is seen that the rotating mass advanced with a rapidity which was about half as great as its exterior velocity of rotation. This circumstance points to another which we may observe when a current of water runs, for instance, through the arch of a bridge into some still water below the bridge. In such a case, I have had occasion to observe that, between the current and the still water, eddies are formed, which move forward, as if rolled by the passing current of water toward the still water, and I have found that the advancing velocity of the mass was pretty nearly half as great as its outer velocity of rotation, which latter was about equal to the velocity of the passing current of water.

I have, unfortunately, not been able to study the movement of rotating masses of water more thoroughly; but since it seems that the laws governing their movement harmonize with those which govern the movement of atmospheric whirlwinds, I think that a careful examination of rotating masses of water would, in all probability, throw much light upon the movements of hurricanes.

Let us now consider a fluid, water for instance, which is considered as rotating uniformly around a vertical axis; but let us disregard the rotation, just as we usually disregard the rotation of the earth with which we move. There will then be an equilibrium at each of the level surfaces of the fluid, and each particle that is upon such a level surface will, when no other forces disturb the equilibrium, be at rest, independently of the rotation. If we now imagine ourselves to be sailing in a boat upon the free surface of the water, or upon any level parallel thereto, for instance, upon the level which is designated in Fig. 1 by the letters $\alpha a_1 b_1 \beta$, while the boat is supposed to rotate with the velocity of the water, it is clear that, since the level surfaces are normal to the resultant of the acting forces, we may sail over the level surface in question just as easily as we can sail upon a horizontal surface of still water, which is acted upon only by the force of gravity.

If this is the case, and if we next consider a body of water which, being contained in a reservoir, has a horizontal surface, upon which only the force of gravity is uniform, and imagine a new mass of water to be let into the reservoir at a certain point, the previous equilibrium is destroyed by the entering water, and does not return until the water

has become uniformly distributed under a new horizontal surface lying somewhat higher. If, on the contrary, a permanent stream flows into the reservoir, the conditions are changed, since the surface of the water does not come to a permanent stand until the influx and the efflux hold each other in equilibrium; then, however, the surface of the water in the reservoir, as well as every other level surface, has a descent toward the efflux, which descent will then obtain over the upper surface of the whole reservoir when the latter is full to the brim, and the point of influx is, for instance, in the middle of the bottom of the reservoir. In perfect accord with this also must be the condition in a permanently rotating fluid, when a constant influx into it is taking place; for if a permanent influx goes on from without at any point of a rotating mass of water or other liquid, the pressure in the rotating mass will be increased at all points, since the surface of the water, and, at the same time, all the parallel level surfaces of constant pressures, must necessarily take a higher stand, and an inclination to the original surfaces of equilibrium corresponding to the influx from the point of influx outward in all directions in which the fluid can flow away.

If this is correct, however, and we further consider that a rotating mass of air can resist the external atmospheric pressure only when the velocity of rotation is of a determined magnitude, it will also be readily seen, both that a great quantity of air must flow from without to the rotating mass along the surface of the earth, and that this permanent current of air must again flow away to the outside in the direction of the level surfaces. When, furthermore, such a rotating mass of air moves over the surface of the earth, it meets with manifold resistances, which diminish its velocity of rotation, and give rise to those violent gusts that are observed during the prevalence of hurricanes. The diminution, thus occasioned, of the velocity of rotation at the surface of the earth, then gives the superiority to the external pressure, and this produces both the aforementioned afflux of external air and the compression of the air in the lower parts of the mass, whereby, on the other hand, the air is again gradually driven away toward the exterior along the level surfaces in proportion to its inflow below toward the center of the whirl.

This explains the screw-shaped formation which is very often observed during the prevalence of small whirlwinds, water-spouts, &c., since the mass of air which rushes in from without along the surface of the earth must, while so rushing in, be set into rotatory motion by the whirlwind. It hereby also becomes evident that in a whirl the direction of the wind along the surface of the earth cannot be perpendicular to the radius of rotation, but on the contrary, and its inclination has been quite correctly adduced by some meteorologists as a proof that an influx of air toward the axis does occur in whirlwinds. It is manifest that the masses of air which rush in along the surface of the earth must have, as is actually observed in nature, a tendency to diminish the velocity of rotation and to increase the diameter of the rotating mass.

After having shown, as I have previously done, that the same laws that govern the movements of water in general also govern the movements of currents of air, and, after having shown in this paper, that the same laws that govern the movements of water in canals and free currents in the sea also govern the movements of the large masses of air which form hurricanes, I consider it almost as a necessary consequence that currents of water in the sea and currents of air in the atmosphere are subject to the same natural laws. Basing my theory henceforth upon the correctness of this assumption, I shall now endeavor briefly to point out how the great currents of air, which are subject to the same laws as the corresponding currents in the sea, move in the atmosphere.

Just as I endeavored, in my former paper on marine currents, to show that the first cause of those general currents must be sought in the fact that the tropical heat, by warming the water of the sea, diminishes its specific gravity to such an extent that its surface is forced to rise to a greater height in the tropics than can be consistent with the equilibrium of the water, thus I also believe that it is proper, generally, to assume that the main currents in the atmosphere are caused by the fact that the air, by reason of its diminished density under the equator, is forced to rise to a considerably greater height than can be consistent with equilibrium in respect to the masses of air which are outside of the tropical regions. Because the height of the atmosphere within the tropics is greater than it is elsewhere, the level surfaces in the upper portions of the atmosphere of the northern hemisphere have an inclination toward the north, and since the air must follow the inclination, this upper portion of the atmosphere must move in a northerly direction in the northern hemisphere. In this manner is produced an equatorial current of air, which is called the anti-trade-wind; but, during the movement of this current toward the north, the force of the earth's rotation makes itself felt and carries the movement more and more over in an easterly direction. While the air under the equator thus rises and rushes away toward the north pole and south pole in the upper portions of the atmosphere, the colder and heavier masses of air, impelled by the force of gravity, rush from the north and south along the surface of the earth toward the equator, because the level surfaces in the lower portions of the atmosphere have an inclination toward the equator, since the pressure of the air is greater outside of the tropics than under the equator; but of course the rotation of the earth again exerts its influence, and gradually changes the north wind, which seeks its way down toward the equator, into a northeasterly wind, which we call the northeast trade-wind, and concerning which I will here remark that it is probably this colder current of air that, by its contact with the ascending calm damp masses of air within the tropics, produces the violent hurricanes, with their frightful electric discharges and immense falls of rain, which occur in West Indian waters.

As the upper currents of air in the atmosphere get beyond the tropics,

the air grows heavier, and gradually (in the northern hemisphere) breaks its way toward the north, alongside of the cold currents of air which move toward the equator. On account of the force of the earth's rotation, the equatorial current of air thus appears as a southwesterly wind, while the polar current of air appears as a northeasterly wind in the northern hemisphere; and thus we see both of these currents are deflected by the force of the earth's rotation, as is the case with the currents of the sea. On both sides of any equatorial current there naturally runs a polar current of air in a southerly direction, and on both sides of every polar current in like manner an equatorial current in a northeasterly direction, and so on round the entire globe.

If we now direct our thoughts to two of these neighboring currents, which move side by side in diametrically opposite directions, and if we suppose that the polar current moves upon the west side of the equatorial air-current which is under consideration, it is evident, from what I have elsewhere previously shown in relation to the Gulf Stream and the polar current which runs west of it, that both the currents of air in question are constantly tending to separate from each other. Since they do not separate, however, the consequence is that while this tendency exists, a rarefaction of the air takes place between the two currents, and in consequence thereof the pressure of the air diminishes toward the dividing surface between these currents, whereby, at every point of the currents referred to, precisely that reaction is caused which is required for the preservation of equilibrium with the force of rotation. From the dividing surface between the aforesaid currents of air, the atmospheric pressure must therefore increase toward both sides, if the currents are to continue their course in their diametrically opposite directions, and the increase of pressure in air-currents for any transverse distance l from the dividing surface can, if it is measured by a column of air $= h$, be computed according to a formula previously given, as applicable to ocean currents, viz:*

$$g\frac{h}{l} = \frac{\sin\theta \sin^2\omega \,.\, v}{13750}, \qquad (5)$$

in which v denotes the velocity of the air-current at the latitude θ, and ω the angle which the direction of the current forms with the east point of the circle of latitude, — the whole in accordance with the formula (70) in my dissertation upon marine currents.† What has been stated shows that the atmospheric pressure in these currents, when they are of the same density, must diminish toward the common dividing surface of the

* NOTE BY THE TRANSLATOR.—This formula should have been

$$g\frac{h}{l} = 2nv\sin\phi,$$

as has been pointed out by Ferrel and Hann. Colding's error resulted from having considered but a portion of the effect of the earth's rotation—an error that also pervades his elaborate memoir on ocean currents. See Ferrel in "Nature," 1871, iv, p. 226, and 1872, v, p. 384.

† [An abstract of this memoir is given in "Nature," vol. v, p. 71 *et seq.*—C. A.]

currents, and that the level surfaces of these currents must necessarily have an inclination toward the common boundary, quite in accordance with what takes place in marine currents; hence it further follows that since the magnitude of the gap formed between the level surfaces of the two currents is dependent upon the velocity of these currents, any chance stoppage of one of these currents will cause it to impinge against the other, either from the NW. or the SE., thus producing an eddy which moves "against the sun." It is evident that so long as the current in question continues its motion, the force of the earth's rotation maintains equilibrium with that force which corresponds to the inclination of the level surfaces toward the dividing surface between the two currents; but, as soon as the motion is diminished, the force of gravity gets the upper hand, and an eddying movement is inevitable. It must now be considered, however, that the density is usually different for the two currents under consideration, since the polar air-current is generally of greater specific gravity than the equatorial current, and the relation between the two air-currents is therefore, in all respects, quite in harmony with the relation which I have pointed out between the Gulf Stream and the polar current along the coast of America. Since, namely, the pressure in the upper part of the atmosphere for the two currents cannot be very different, the pressure in the lower part of the atmosphere must be different for air-currents of different specific gravities; and since two essentially different pressures cannot exist by the side of each other, the consequence is that the current having the greater specific gravity must flow sidewise into the current having the less specific gravity, in proportion to the excess of pressure. Since now, as has been said, the polar current usually has the greater specific gravity of the two currents, it follows that, in proportion to the excess of pressure of the polar current above the equatorial current running east of the same, under otherwise undisturbed atmospheric conditions, a considerable portion of cold air will rush from the northwest into the equatorial current, whose air-pressure is thereby increased as far as the cold air penetrates. It is, however, at the same time, evident that the cold air which thus penetrates will, as soon as it penetrates into the warm air, which is full of aqueous vapors, produce a condensation of these vapors, from which a cold rain from the northwest or west will result. It must also be evident from the foregoing that under disturbed atmospheric conditions eddying winds may likewise be formed, which, under extraordinary circumstances, may increase to tornadoes or hurricanes, with all the corresponding natural phenomena.

We have now considered the natural conditions that must present themselves upon the west side of an equatorial current when a polar current runs along it toward a southwesterly direction, and we will now proceed to examine what must be the conditions upon the east side of such an equatorial current when a polar current runs alongside of it in an opposite direction toward the southwest. In the first place, it is

clear that since the equatorial current moves in a northeasterly direction, it will be affected by the force of rotation; and therefore this current, as already remarked, cannot pursue the given direction unless the air-pressure increases from west to east right across the current, as formula (5) requires. But, on the other hand, it is also evident from what has been said that the polar current running east of the same is likewise unable to pursue the given direction unless the air-pressure in this current similarly increases from east to west, according to the law laid down in formula (5). For these two currents, therefore, the level surfaces have an ascent toward each other, and hence it results that both currents are kept braced against each other by the force of rotation, while each of them seeks to crowd the other out of its place. If currents of air are of different specific gravities, the one having the greater specific gravity must, as in the foregoing case, penetrate into the other; and since it is generally the polar current whose specific gravity is the greater, this stream will usually penetrate from the southeast into the equatorial current, and give rain from the southeast or south. An essential difference between the conditions upon the east side of the equatorial current and the condition upon the west side of the same is that while the air-pressure upon the west side of the equatorial current is always relatively low, the pressure upon the east side of the same current is always relatively high. The most remarkable difference, however, is perhaps this, that although in the region between the equatorial current and the polar current which runs east of it calms may occur similar to those which the great air-whirls produce upon the west side of the equatorial current, yet a whirlwind of any magnitude can never be formed upon the east side of the equatorial current, because the force of gravity here works in the same direction as the centrifugal force, thus tending to scatter the masses of air, while upon the west side it works against the centrifugal force and holds the masses of air together. If we now further consider that, in the very nature of the case, the rotatory movements that take place upon the east side of an equatorial current must be "against the sun," while those which occur upon the west side of such a current must be "with the sun," the reason is at once seen why all revolving tornadoes and hurricanes must rotate against the sun in the manner which experience has shown.

If we now imagine ourselves to be in a polar air-current, and moving under normal conditions across it in a westerly direction toward the equatorial current, we shall, according to the preceding, from a relatively cold and dry northeasterly wind, with a high barometric pressure, gradually find the wind, under a rising air-pressure, changing to an easterly direction, and afterward, under a slightly diminishing air-pressure, changing into a rainy but somewhat milder southeasterly wind. Under a constantly diminishing air-pressure, with milder and moister air, the wind passes through the south over to the southwest, and we then find ourselves in the southwesterly equatorial current, in which the state of

the barometer is low and the temperature relatively high. If we now go farther toward the west, the pressure of the air diminishes constantly, but no change takes place in the direction of the wind. Gradually, however, the pressure of the air begins to rise, while the wind shifts round more to the west and grows somewhat colder. During a constantly rising atmospheric pressure, the wind passes through the west, and becomes a cold, rainy, northwest wind. If we continue our progress toward the west, the pressure of the atmosphere rises still higher, the wind shifts round more to the north, the air becomes clear, and we come at last, under a constantly rising atmospheric pressure, through a northerly wind into the next northeasterly polar current. If we move in the contrary direction, *i. e.*, from west to east, these phenomena will, of course, be reversed. What I have desired hereby to show is, that if we travel from east to west, when everything is in a normal state, we shall see the direction of the wind gradually change in the manner stated by Professor Dove in his well-known law of rotation, according to which the wind most frequently turns in a direction with the sun, and that by traveling in an opposite direction, from west to east, we shall see the direction of the wind change according to the opposite law. Now, since Dove's law of rotation has been confirmed, in the main, by the observations which have been made in various countries,* one is led to assume that the atmosphere has a movement sometimes from west to east, and sometimes from east to west around the earth, which seems in itself to be quite probable, but one is led, at the same time, to the conclusion that the easterly movement is the preponderant one. That this, moreover, is really the case, I hope the following will plainly show. From what I have said in the foregoing, it is evident that if the moving masses of air which are conveyed from the lower to the higher degrees of latitude by the equatorial air-currents were of the same magnitude as the masses of air which are carried back by the polar air-currents from the higher to the lower degrees of latitude—which would, of course, necessarily be the case if the air from the lower to the higher degrees of latitude did not bring with it moisture, which is thrown off on the way—then, for each separate degree of latitude, it would be necessary that the sum of all the pressures which the force of the earth's rotation would exert upon the masses of air impelled toward the poles from west to east should be equal to the sum of all the pressures which the same force would exert from east to west upon the masses of air which moved from the pole toward the equator. In such a case, taking all things together, there would have to be an equilibrium between the forces which would respectively move the atmosphere in an easterly and westerly direction. The case is, however, different in reality, since the mass of air which moves toward the poles brings with it a considerable quantity of aqueous vapors, in consequence of which the mass of air which rushes toward the poles is always con-

* See Professor Holten's paper in the Videnskabens Selskab Oversigt for 1865, p. 113.

siderably greater than the quantity of air which, at each separate degree of latitude, returns toward the equator. Hence it evidently follows that the atmosphere in its entirety, with the excess of pressure which takes place from west toward east, must move from west to east around the firm surface of the earth; and hence, again, it follows that Dove's law of revolution for the wind must be a natural law.

I shall, for the present, not consider further the conclusions which may probably present themselves, and that may be deduced with regard to the phenomena of wind and weather. It seems, however, to be pretty clear that these deductions may be more important than anything that we have hitherto known on the subject we have been considering.

J. .

ON THE WHIRLWIND AT ST. THOMAS ON THE 21ST OF AUGUST, 1871.

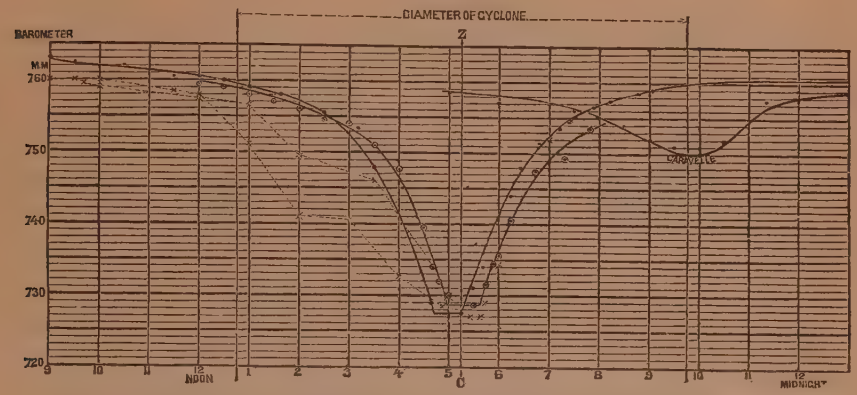
[We here append a translation of Hann's extracts (Zeitschrift, x, p. 141), from a second memoir by Colding, entitled "On the Whirlwind at St. Thomas on the 21st of August, 1871," and which is published at page 10 of the volume for 1871 of the "Proceedings of the Danish Academy."]

On the 21st of August, 1871,* a whirlwind passed over the West India Islands in the direction from ESE to WNW. The reports show the average velocity of its progress to have been 12 English miles per hour. The center of the hurricane passed directly over the city of St. Thomas about 5 o'clock p. m. During the whole day before the outbreak of the hurricane the wind blew from NNE to ENE. The barometer before noon stood at 765.5 millimeters, and fell about 1.5 millimeters from morning to evening. The pressure continued falling throughout the night, and the wind increased in force. About 4 a. m. of the 21st, the barometer stood at 763 millimeters, and remained stationary at this point until 9 a. m. The wind blew in gusts, with squalls from the east and northeast, and heavy rain fell. At 12.30 p. m., the barometer stood at 760; the wind was more northerly, and blew in fearful gusts. At 2.30 p. m., the pressure was 755.5 millimeters; the wind veered to northwest at 3.30 p. m., and blew with terrific power. The heaviest winds, which caused great damage, occurred about 4.30 and 5 p. m., and came from the northwest. At 5 p. m., it suddenly became still, as the center of the hurricane drew near. The city was enveloped in a thick, dark fog, and the air was unnaturally quiet. During this calm, the pressure reached its lowest point, 727.5 millimeters. After an interval of 35 minutes, the hurricane began anew with heavy squalls

* The subsequent path and other phenomena of this hurricane, which passed over Punta Rassa on the 23d, were successfully predicted from day to day in advance by the present translator in the tri-daily weather probabilities of August, 1871, as published by the Army Signal Office.—C. A.

from the southwest to southeast; at the same time the barometer began to rise. Five series of meteorological observations during this hurricane are at hand. The observed values of the atmospheric pressure for three of these are graphically presented in Fig. 3.

FIG. 3.



The most complete observations, corresponding to the curve through the simple points (.), were made on the French steamship La Ville de St. Nazaire, Captain d'Etroyat. The points enclosed in circles are entered according to the observations on the ship Tyne, Captain Taylor. Both these series of observations were instituted in the harbor of St. Thomas. The curve designated by *Caravelle* is drawn according to the observations on the steamer of the same name, which was 4 or 5 miles north of Porto Rico, at a distance of 54 nautical miles from St. Thomas.

The whirlwind began at St. Thomas about 12.30 p. m. and ceased about 9.30 p. m. Its duration was therefore 9 hours. The central calm passed St. Thomas in 0.6 hours. As in the previous case, we designate the radius of the calm space by $\alpha = 0.3$ hours $= 3.6$ miles, since the velocity of its progress must, according to the observations, be taken at 12 miles per hour; therefore the radius of the whole whirl (adopting the previous notation) is $\alpha + H = 4.5$ hours $= 54$ miles, and therefore $\frac{H+\alpha}{\alpha} = 15$ and $\frac{H}{\alpha} = 14$.

If we substitute these values in equation (3), we obtain—

$$X = 2.3 \log\left(1 + 14\frac{x}{H}\right) - 0.032 \operatorname{tang}^{-1}\sqrt{14\frac{x}{H}} + 0.577\sqrt{\frac{x}{H}}\left(0.214 - \frac{x}{H}\right)$$
$$+ 0.0625\frac{x}{H}\left\{\left(\frac{x}{H}\right)^2 - 0.107\frac{x}{H} + 0.015\right\}.$$

Whence for the following values of $\frac{x}{H}$ we obtain the corresponding values of X and z:

$\frac{x}{H} =$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
$X =$	0.87	1.31	1.58	1.78	1.93	2.04	2.12	2.19	2.24	2.27
$z =$	10.0	17.0	21.5	24.5	27.0	28.5	29.5	30.5	31.0	31.7

The values of the pressure z given in the lowest line are those which, according to d'Etroyat's observations, belong to the corresponding values of $x = 0.1\,H$, &c. But, according to equation (3), we can determine the constant $\frac{V^2}{g}$ by means of each pair of X and z. We have for this purpose the ten numerical equations

$$\frac{V^2}{g} = \frac{10.0^{mm}}{0.87}; = \frac{17.0}{1.31}; = \frac{21.5}{1.58}, \text{ &c.};$$

and as the mean of these ten values we find

$$\frac{V^2}{g} = 13.7^{mm} \text{ of mercury, according to d'Etroyat;}$$

similarly,

$$\frac{V^2}{g} = 13.2^{mm} \text{ of mercury, according to Taylor.}$$

By using these constants, we can now, for each value of $x = 0.1\,H$, &c., compute the corresponding value of z. This computation, executed for both the series of observations by d'Etroyat and by Taylor, gives the following result:

$\frac{x}{H} =$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
					D'Etroyat.					
z observed..	10.0	17.0	21.5	24.5	27.0	28.5	29.5	30.5	31.0	31.7
z computed .	11.9	17.9	21.7	24.4	26.5	28.2	29.1	30.1	30.8	31.2
					Taylor.					
z observed..	10.0	16.5	21.0	23.5	25.5	27.0	28.0	29.0	29.5	30.5
z computed .	11.5	17.2	20.8	23.4	25.4	27.0	27.9	28.8	29.5	29.9

The agreement is therefore almost perfect. D'Etroyat's observations give for $\frac{V^2}{g}$ the value 13.7 millimeters of mercury, or 460 feet of air; Taylor's observations give 440 feet of air. From these it follows that $V = 120$ feet or 39 meters and 117 feet or 38 meters. Since the velocity of the forward progress of the whirlwind was 12 miles, or 20 feet per second, therefore must the greatest velocity of the wind on the right side of the whirl, where the rotatory and the progressive movements take place in the same direction, be considered to be 140 feet or 45.5 meters; but on the left side, where the inverse is the case, it becomes 100 feet or 32.5 meters. For $x = H$ the equation (1) gives in our case $v = 68$ feet as the velocity of rotation at the outer limit of the whirl. This would give a velocity of 88 feet on the right and 48 feet on the left-hand side. Therefore between these limits ranged the velocity of the wind within the cyclone of the 21st August, 1871.

K.

ON THE RELATION BETWEEN BAROMETRIC VARIATIONS AND THE GENERAL ATMOSPHERIC CURRENTS.

By Mr. Peslin, Mining Engineer at Tarbes.

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(1) *The Laws of the Winds given by the Synoptic Weather Charts.*

If we study the synoptic charts that the Imperial Observatory at Paris has collected in the "Atlas of the General Movements of the Atmosphere," we are struck by the generality of a fact which, at first thought, seems contrary to the laws of mechanics. The atmospheric currents never move in a direct line from the region of high barometric pressure toward the region of low pressure; but, according to the numerous observations recorded in the synoptic charts, the direction of the wind is more often nearly that of the tangent to the isobarometric curves. One might conclude from this that the variations of atmospheric pressure have little or no influence upon the direction of the wind; that the movements of the terrestrial atmosphere are regulated by some foreign force, which has no relation to the pressure indicated by the barometer.

However, a more thorough examination of the synoptic charts enables us to recognize a certain co-relation, on the one hand, between the direction of the atmospheric currents and the direction of the barometric variations, counted normally, to the current, and, on the other hand, between the force of the wind and the rapidity of this transverse variation of the pressure. For the sake of clearness, let us personify the wind, and suppose that Eolus faces always toward the point of the horizon toward which he blows. We shall perceive, in the first place, that in the synoptic charts the high barometric pressures are always on his right hand, and the low pressures on his left hand. In the second place, we shall see that when the synoptic chart shows regular and violent winds over a certain extent of country, the isobars cross over this region, and traverse it in parallel lines close together.

According to the examination that we have been able to make of the published synoptic charts, the preceding laws are very general, and can be safely applied to the whole temperate zone of our hemisphere; they are a simple extension of known laws of the movements of the air in cyclones and tempests. We shall now seek to give their explanation according to the principles of mechanics.

(2) *Mechanical Conditions of the Existence of an Atmospheric Current.*

I assume that some cause initiates in our hemisphere a general atmospheric current; that is to say, a current of air following a constant direction over a large extent of country. I will now seek the

conditions that the constitution of the atmosphere imposes in order that this current may be maintained for an indefinite length of time, and in order that the diurnal rotation of the earth shall not modify the direction which the current has at the surface of the globe. Let A be one of the points of the region over which the atmospheric current prevails. Let B A be the direction of the current, V the velocity with which the air moves. Let A y be the meridian of the point A; A x the perpendicular to A y, or the tangent to the parallel through the point A. Let us represent by λ the latitude of the point A, and by $\Omega = \frac{2\pi}{86400'}$ the angular velocity of the diurnal rotation of the earth. The curve really described in space by a particle of air is obtained by compounding the apparent movement of this particle on the surface of the earth; that is to say, the translation corresponding to the velocity of the current, with the movement of the terrestrial surface, or the translation corresponding to the diurnal rotation.

I decompose the diurnal rotation into two component rotations, the first having for its axis that radius of the earth which passes through the point A, the second having for its axis the terrestrial radius perpendicular thereto and in the plane of the meridian of the point A. The angular velocities of these component rotations will be, for the first, $\Omega \sin \lambda$, and for the second $\Omega \cos \lambda$.

Let us first consider the effect of the first rotation. The apparent trajectory of the particle of air which passes by A being the line A P, the real trajectory will be a curve A M, determined in polar co-ordinates by the equations A M = A P = V t. Angle P A M = $\Omega\, t \sin \lambda$, where t is the time employed by the particle of air in describing the arc A M.

The trajectory described is a curve. Consequently the particle of air is subject to the action of a force whose value depends upon the curvature of the trajectory, and is easy to calculate according to the principles of mechanics.

The tangent to the trajectory at A is A P, for the limit of the angle P A M is 0 for $t = 0$. The velocity at A is V, for this velocity is the limit of the ratio of the arc A M, or of the chord A M = V t, to the time t required to describe it. Consequently, the effect of the force that we desire to calculate, acting through the time t upon the particle of air, is to produce a deviation, represented in our figure by the line P M. Let m be the mass of the particle of air and m F the force that acts upon it. We shall, according to mechanical principles, have

$$\mathrm{P\,M} = F \cdot \frac{t^2}{2}.$$

The figure gives us the geometrical relation

$$\mathrm{P\,M} = \mathrm{A\,M} \cdot 2 \cdot \sin\left(\frac{\mathrm{P\,A\,M}}{2}\right),$$

or

$$\mathrm{P\,M} = 2\,V t \sin \frac{\Omega\, t \sin \lambda}{2}.$$

Comparing these values, and passing to the limit by making t diminish to zero, we shall obtain, for the value of the force F,

$$F = 2\,V\,\Omega\,\sin\lambda\,.$$

As to the direction of the force, it is that of the deviation P M perpendicular to the line bisecting the angle P A M, and passing to the limit we obtain a direction A F perpendicular to A P, or the direction of the current at the point A.

The force $m\,F$, whose direction and value we have determined, is that known in mechanics as a composite centrifugal force. We will now apply to our special case the general theory, by means of which we pass from forces of apparent movement to real forces.

We will now determine the effect of rotation about the terrestrial radius passing through the point A. The second rotation, that which takes place about the radius perpendicular thereto, will give to the real trajectory a new curvature, and consequently we should have to conclude the existence of a new corresponding force; but this second composite centrifugal force is feeble relatively to the first, and does not seem to manifest itself in existing meteorological observations. In order to simplify our formulas, we shall, in what follows, neglect it as being insensible.

A calculation analogous to that which precedes shows that if the air moves parallel to the terrestrial surface, or if the level of the particle of the air m does not vary, the second composite centrifugal force is vertical and has for its value

$$2\,m\,V\sin\varphi\;\Omega\,\cos\lambda$$

(φ being the angle that the velocity V makes with the meridian).

This force having the same direction as the force of gravity, and extremely feeble in comparison with it, should exert an influence proportional to its value. We do not think its effects can be clearly distinguished from those of the weight of the air. When the air is animated by an ascending or descending movement, such that the velocity V of the particle m has a vertical component $\frac{dr}{dt}$, the composite centrifugal force that we are studying has a second component

$$2\,m\frac{dr}{dt}\,\Omega\,\cos\lambda\,,$$

which is horizontal and perpendicular to the meridian. It is possible that this second component produces some appreciable effects in meteorological phenomena when the vertical movements of the air become important, as, for example, in storms and hurricanes.*

* NOTE BY THE TRANSLATOR.—It will be perceived that in these formulæ Peslin treats of the rotation of the earth to the neglect of the rotation of storm-winds about their centers.

(3) *The Law of Variation of Barometric Pressure within Atmospheric Currents.*

We shall show that when any region of the earth is traversed by a general atmospheric current which preserves its direction notwithstanding the diurnal rotation, one can conclude with certainty as to the existence of horizontal forces perpendicular to the direction of the current and affecting every particle that is in motion.

The forces which can affect any particle of the earth's atmosphere may be divided into two classes: First, the internal forces, or those exerted by neighboring particles—in other words, the pressure; second, the external forces, or those exerted by exterior bodies. The external forces can be reduced to, first, the attraction exerted by the earth, or the weight of the particle; and, second, the action of the solar heat. But even this last is not a force, properly so-called, for it does not tend to displace the particle of air or make it to move in one direction rather than the opposite. Its only direct effect is a variation of the internal living force, and consequently of the density.

If, then, I neglect the problematic influence of the moon and of other celestial bodies, and if, moreover, I expressly leave out of consideration the forces due to atmospheric electricity, I shall find no exterior force that has a horizontal component. There will remain then to me, in order to take account of the forces mF which solicit the particles of the current, only the variations of atmospheric pressure in a horizontal direction.

Let us imagine a parallelopipedon cut from the mass of moving air, and having a base whose surface is S, in a vertical plane parallel to the direction of the current, and a height equal to Δr. The volume of the parallelopipedon will be $S\,\Delta r$, and the total mass of particles of air which it contains $M = \frac{\rho}{g} S\,\Delta r$ (where ρ is the density of the air, and $g = 9^{m}.8088$ is the value of gravity.

The forces exerted upon the mass M due to the particles of the surrounding fluid have, for resultants, pressures upon the faces of the parallelopipedon. As these pressures are normal to the faces upon which they act, the pressures upon the horizontal faces and upon the vertical faces normal to the direction of the current give no components having the direction of the forces mF. We have then to take account only of the pressures p and $p + \Delta p$ exerted upon the two vertical bases of the surface S; and recollecting that the resultant of all the forces mF which affect the particles contained in the parallelopipedon ought to be equivalent to the difference between these two pressures in opposite directions, we shall have the equation*

$$S\,p - S\,(p + \Delta p) = mF;$$

* The theory that we shall here develop in order to obtain the law of pressures is identically the same as that which, in mechanics, serves to establish the fundamental equation of the motion of fluids.

whence, substituting the value of M and dividing by S,

$$\Delta p = -\frac{\rho}{g} F \Delta r.$$

We can also replace F by its value determined previously, and the formula then becomes

$$\Delta p = -\frac{\rho}{g} \cdot 2\, V \cdot \Omega \sin \lambda\, \Delta r.$$

(4) *Application to the Synoptical Charts.*

It is easy to apply these theories to atmospheric currents, and to show that they give the same laws that we have deduced from the examination of synoptic charts.

The forces $m\,F$ have no components in the direction of the current; consequently, the pressure ought not to vary in this direction: in other words, the direction of the wind ought to be tangent to the curve of equal barometric pressure. The direction in which the pressure increases transversely to the current is opposite to that of the forces $m\,F$. It should change when the direction of the current changes; and in our hemisphere, considering the direction of the terrestrial rotation, we recognize by the examination of the figure which gives the force F that the highest pressure should always, on the synoptic chart, be to the right of the current. Finally, the coefficient $\frac{\Delta p}{\Delta r}$ which measures the rapidity of the transverse variation of the pressure increases proportionally to the force F; that is to say, increases on the one hand as the velocity V of the moving air, and, on the other hand, increases in proportion to the sine of the latitude of the region under consideration. If any region of the earth is traversed by a violent atmospheric current, the curves of equal barometric pressure ought, in traversing this region, to draw closely together, and so much the more for a given violence of the wind in proportion as the region is further removed from the equator.

(5) *Extension to the Case of Rotatory Movements.*

These laws are those that relate to atmospheric currents of constant direction and intensity; when the movement of the air is not rectilinear, these cease to be rigorously applicable. It is necessary then to combine the composite centrifugal force with the forces which correspond to the apparent movements of the particle of air. These forces are: $m\frac{dV}{dt}$ in the direction of the current, and $m\frac{V^2}{\mathrm{R}}$ in a direction normal to the current, R being the radius of the curvature of the apparent trajectory. Consequently the formulæ which give the variation of barometric pressure become

$$\frac{dp}{ds} = -\frac{\rho}{g} \cdot \frac{dV}{dt};$$

$$\frac{dp}{dr} = -\frac{\rho}{g} \cdot \frac{V^2}{\mathrm{R}} - 2\frac{\rho}{g} V \Omega \sin \lambda.$$

These are the formulæ which ought to be applicable in studying the rotatory movements of the air in cyclones and storms. We have already stated, at the beginning of this memoir, that the laws which we have previously enunciated apply to the movements of the air in tempests, and that they have been already recognized and formulated by numerous observers. We must, then, conclude that, even in meteorological phenomena, where the apparent movement of the air is most irregular and violent, the composite centrifugal force retains a preponderating influence, such that the variations of barometric pressure are controlled principally by this force, according to the laws that we have developed.

But if our formulæ give the laws of tempests as a particular case, it is important to remark that they are more general still, and that they are applicable to all the movements of the air in our hemisphere. It is not necessary that there should be a storm (that is to say, a rotatory movement of the atmosphere accompanied by rain) in order that the direction of the winds should obey the preceding rules. Every terrestrial region where a barometric depression is produced will be surrounded by winds circulating in a direction opposite to that of the hands of a watch; and conversely, if the barometric pressure is high over any region, the winds prevailing upon the borders of this region will circulate in the same direction as the hands of a watch. It is only necessary to glance upon the synoptic charts in order to ascertain how fully these rules as to the direction of the winds are confirmed by the observations that are therein presented.

(6) *Explanation of the Variation of Barometric Pressure with the Latitude.*

Our theory permits us to give an explanation of some of the facts, generally accepted, relative to the variations of barometric pressure upon the surface of the earth.

The barometric pressure reduced to the level of the sea is not constant, but varies with the latitude. Its mean value at the equator is about 758 millimeters. It increases from the equator to a parallel between 30° and 40°, and there attains a maximum value of 762 to 764 millimeters. If we proceed to higher latitudes, the pressure diminishes, and in the polar regions it is probably less than 756 millimeters.* This variation of pressure with latitude is also easily confirmed by the synoptic charts. On each chart we see designated a region of high pressure whose center is generally in the middle of the Atlantic near the parallel of 30°. The pressure at the center often attains 775 millimeters, and sometimes 780. The winds are feeble near the center, but on the borders of this region they become stronger. On the east and south borders, they blow from points of the compass comprised between north and east, and constitute the trade-winds. On the northern border, the winds blow very generally from the west, and are connected with the anti-trade currents.

* Kämtz's Meteorologie, Martin's edition, p. 258.

According to our theory, the existence of these winds on these borders suffices to explain the high pressure that is experienced in the central regions; it seems to us, then, very probable that the variation of the pressure with latitude ought to be attributed to the permanent currents that the earth's atmosphere presents. The pressure should increase then from the equator to the parallel of 30° in the whole region where the trade-winds of the equatorial zone prevail; it should decrease from the parallel of 40° to the pole over the whole region where the return current or the contra-trade of the temperate zone prevails.

It is on the parallel where the interchange is made of the second current for the first that the pressure attains its maximum value.

(7) *Explanation of the Increase of the Monthly Oscillations of the Barometer from the Equator to the Pole.*

One of the most prominent facts that is presented by the observation of the barometer is the rapid increase of the irregular oscillations in proportion as we go away from the equator. The difference of the monthly extremes, which at the equator scarcely surpasses on the average two or three millimeters, is ten millimeters at the parallel of 30°, and becomes thirty and even forty millimeters in the polar regions.* This enormous variation of the monthly barometric oscillation was indicated a long time ago by De Saussure, who has said that any hypothesis destined to explain the barometric oscillations ought first of all to take account of their increase with the latitude. Let us see if our theory gives any satisfaction as to this point.

In the formula which gives the transverse barometric variation for an atmospheric current of the velocity V, and which is

$$\frac{\Delta p}{\Delta r} = -2\frac{\rho}{g} V \Omega \sin \lambda,$$

the sine of the latitude enters as a factor. An atmospheric current of constant intensity produces, then, on its borders variations of barometric pressure which are very unequal, according as it is developed near the pole, or near the equator. If we represent by unity the variation of the barometer in the polar regions, it becomes 0.71 at the latitude of 45°, 0.50 at the latitude of 30°, and 0.26 at the latitude of 15°.

Let us apply to the numbers cited by Kämtz a correction for the latitude calculated according to these considerations; in other words, let us divide by sin λ the monthly oscillation of the barometer in order to reduce it to that which would have been produced at the pole of the earth by a current of the same intensity. We shall obtain a series of numbers which increase with the latitude, but in a much less rapid degree than previously. The monthly oscillations reduced to the pole become ten to fifteen millimeters for the equatorial regions, twenty millimeters for the parallel of 30°, and thirty-five to forty millimeters for the polar regions.

* Kämtz, Meteorologie, p. 281.

It remains to be shown whether the irregular atmospheric currents and storms which produce in each month the extreme variations of the barometer increase in intensity with the latitude; whether this intensity doubles as we pass from equatorial regions to temperate zones and trebles when we pass to the polar regions.

A precise verification cannot be made at present. We possess no direct observations upon the mean velocity of the atmospheric currents in different latitudes; but we can assert that the ratios of the intensities to which our theory leads us do not differ very much from the reality. It is well established that, as the regular winds diminish, the frequency and the violence of the irregular currents and of the tempests increase in proportion as we depart from the equator. The reason would seem to be that indicated by Kämtz.* The first cause of every current in our atmosphere is an irregularity of temperature. Now, in proportion as we proceed from the pole toward the equator, the thermometric variation for any change in latitude becomes more rapid; the distribution of temperature upon the same parallel becomes more irregular. In general, we think it certain that our formula suffices to explain the enormous variation of the monthly barometric oscillation as one passes from the equatorial to the polar regions.

(8) *Calculation of the Velocity of the Wind from the Variations of Barometric Pressure.*

The relation that we have found between the velocity of the air in any atmospheric current and the variation of barometric pressure in a direction transverse thereto should permit us, inversely, to calculate the velocity of the air when we know the law of the variation of the pressures. The synoptic charts, by giving us for every day the law of the distribution of pressure over a certain region of the earth, enable us to deduce the mean velocity that should be presented by the atmospheric currents prevailing over this region. To this end it suffices to resolve the equation

$$\Delta p = -2\frac{\rho}{g} V \Omega \sin\lambda \, \Delta r$$

with reference to the velocity V considered as an unknown quantity: thus we obtain

$$V = \frac{-g\,\Delta p}{2\rho\,\Omega \sin\lambda\,\Delta v}.$$

In the synoptic charts the isobars are traced for pressures differing by five millimeters. For the value of the arbitrary distance Δr, I take the distance of the two isobars which include the point under consideration. The corresponding value of Δp would be equivalent to a height of 5 millimeters of mercury, and we consequently have

$$\frac{\Delta p}{\rho} = \frac{0^{m}.005 \times 13.596}{0.001293 \times \frac{p}{0.760} \times \frac{1}{1+at}}$$

* Kämtz, Meteorologie, p. 281.

(where p is the pressure and t the temperature of the air whose density is represented by ρ).

Upon the synoptic chart, the natural unit of length is the degree of the meridian, which is represented at any point by the distance between the lines corresponding to the terrestrial parallels. I will call δ the value of the distance Δr expressed in this unit. As our formula supposes that the meter is taken as the unit of length, the value of Δr that we shall use will be

$$\Delta r = \frac{10\,000\,000^{m}}{90} \cdot \delta \quad .$$

(90° of the meridian of the earth are equivalent to 10,000,000 meters). We have, finally,

$$g = 9^{m}.8088; \quad \Omega = \frac{2\pi}{86400} = \frac{2 \times 3.1416}{86400}.$$

After all substitutions have been made, the formula which gives the value of V becomes

$$V = \frac{0.005 \times 13.596 \times 9.8088 \times 86400 \times 90}{2 \times 0.001293 \times 2 \times 3.1416 \times 10\,000\,000} \times \frac{0.760}{p} \times \frac{1 + \alpha t}{\delta \sin \lambda};$$

whence, by making the calculations as indicated,

$$V = 31^{m}.91 \times \frac{0^{m}.760}{p} \times \frac{1 + \alpha t}{\delta \sin \lambda}.$$

In this formula, there enter four elements—the barometric pressure p, the temperature t, the distance of the isobars δ, and the latitude λ; but the daily variations of the two first elements exert only a feeble influence, which may be neglected in a first approximation. The pressure p in the synoptic chart has reference to the level of the sea, and varies between the limits 715 and 785 millimeters; consequently, the factor 0.760 remains always comprised between the limits 0.907 and 1.06. As to the temperature t, its variations have a greater importance; but, as they are not given upon the synoptic charts,* we are obliged to neglect its daily variation, and can take account only of the mean temperatures. In order to simplify the matter, we have assumed that this mean temperature, supposed to be reduced to the level of the sea, depends only upon the latitude λ, and we have formed a table of double entry giving the values of the velocity V corresponding to various values of λ and δ. This table has been formed especially in reference to the zone covered by the synoptic charts, that is to say, the regions of the North Atlantic and of Western Europe comprised between the parallels of 30° and 60° of north latitude.

p=0.76.	λ=30. t=20.	=35 =17.5	=40 =15	=45 =12.5	=50 =10	=55 = 7.5	=60 = 5
	m.	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
δ=1.0	V=68.5	V=59.2	V=52.4	V=47.2	V=43.2	V=40.0	V=37.5
1.5	45.6	39.5	35.0	31.5	28.8	26.7	25.0
2.0	34.2	29.6	26.2	23.6	21.6	20.0	18.8
2.5	27.4	23.7	21.0	18.9	17.3	16.0	15.0
3.0	22.8	19.7	17.5	15.7	14.4	13.3	12.5
4.0	17.1	14.8	13.1	11.8	19.8	10.0	9.4
5.0	13.7	11.8	10.5	9.4	8.6	8.0	7.5

* Those, *e. g.*, of the Paris Observatory.

The application of this table to the synoptic charts is easy. Thus, let us suppose that we are studying the charts of the last ten days of June, 1864, and that we desire to find the average force of the trade-wind which, during those days, prevailed upon the Atlantic along the coast of Portugal. By comparing the barometric pressures noted by the different ships that passed out a short distance from this coast with the pressures observed at Lisbon, which remained very nearly constant during the ten days, we find for δ very accordant values, varying only between 3.0 and 4.0. The latitude is 40° north, since the parallel of 40° cuts the coast of Portugal between Lisbon and Oporto. From this we conclude, by means of the above table, that the force of the wind must have varied between 13 and 17 meters per second, and that its mean value was very nearly 15 meters per second.

Let us take a second, more complicated example, that of a whirling movement of the air. The synoptic chart of the 14th of January, 1865, shows that on this day a storm raged upon the coasts of France and England. Let us seek the force of the wind which blew over the center of France, between Paris and Bordeaux. The barometric pressure at 8 o'clock in the morning was 738.6 millimeters at Paris and 753.6 millimeters at Bordeaux and Toulouse. The difference, 15.0 millimeters, corresponds to a distance which, reduced normally to the direction of the atmospheric current, is 4°.5 of the meridian.

We have, then, to take from the table that value of V which corresponds to

$$\delta = \frac{4.5}{3} = 1°.5$$

at latitude 45°. This value is $V = 31.5$. Such would be the force of the wind if the atmospheric current were [linear?], but as the air in the storm has a turning movement, we can accept this figure only after having applied to it a correction. I do not think it would be useful to enter into the details of the calculation of this correction. It is made by applying the formula that we have given for the turning movement, and the value of the correction depends essentially on the ratio of the curvature of the trajectory [with reference to the distance of the point considered as the center of depression about which the wind rotates] and the velocity of progression of the center. In the present case, the value of the correction will be found equal to 5 or 6 meters, and we are led to adopt the figure 26 meters per second as representing the average force of the wind that prevailed between Paris and Bordeaux.

The synoptic chart gives, indeed, the force of the wind at every point, but the sign [or figure] representing this force corresponds to an indefinite epithet which cannot be translated into precise figures. We can, therefore, not verify the exactness of the result which our formula gives for the force of the wind; we can only state whether there exists a general accordance between the results of the calculation and those of the

observation; and it is easy to assure ourselves that this is, in general, very satisfactory.

But we ought not to conceal the fact that some discordances present themselves when we enter into details; that our theory does not explain certain observations of the force and direction of the wind recorded in the atlas. These exceptional facts, it seems to us, ought to be explained either by local influences, such as the attraction of coasts, of valleys, of mountains, or by periodical or accidental meteorological phenomena, such as the morning breezes, gusts of wind, thunder-storms, &c. The proportion of discordances to the accordances is too small to throw any doubt upon the exactness of the theory.

(9) *Application of the same Theory to Ocean Currents.*

I will terminate this memoir by an application which does not directly refer to meteorological phenomena, but which has a certain interest in reference to the general physics of the globe. Let us consider a grand ocean current, as for example, the Gulf Stream along the coast of North America. A particle of the surface moving with the velocity V is subject to two forces: gravitation, a vertical force whose intensity is $m\,g$, and the composite centrifugal force, a horizontal force whose direction is normal to that of the current, and whose intensity is $m\,F = 2\,m\,V\,\Omega\,\sin\lambda$. In order that the particle of water should not deviate, but continue to progress in the same direction with the same velocity V, it is necessary that the free surface of the sea should be, at this place, not horizontal but normal to the resultant of the forces $m\,g$ and $m\,F$; that is to say, that in a section taken normal to the direction of the current the free surface presents an inclination, I, to the horizontal plane whose value satisfies the equation

$$\text{tang}\,I = \frac{m\,F}{m\,g} = 2\,\frac{\Omega}{g}\,V\sin\lambda.$$

Thus, in the same way that the trade-winds and the anti-trades are the cause of the increase in the barometric pressure toward parallels 30°, in precisely the same way the Gulf Stream, which reproduces at the surface of the sea the circulation of the general currents of the atmosphere, gives rise to an elevation of the level of the sea at the center of the Atlantic, or to an accumulation of water in the region about which the current circulates. Let us calculate the inclination I and the difference of level to which this inclination gives rise.

If in the formula which gives tang I are substituted the values of

$$g = 9^{m}.8088 \text{ and of } \Omega = \frac{2 \times 3.1416}{86400},$$

we obtain

$$\text{tang}\,I = \frac{4 \times 3.1416}{86400 \times 9.8088}\,V\sin\lambda = 0.00001483\,V\sin\lambda,$$

whence—

$$I = 3''.06\,V\sin\lambda.$$

This inclination I is very feeble, but as the breadth L of the current of the Gulf Stream is very considerable, the difference of level between the two borders of the current $\Delta = L \tan I$ attains a considerable value. Thus, let us take as the base of our calculation the figures given by Kämtz in his Meteorology, or those published more recently by A. D. Bache, Superintendent of the United States Coast Survey. We shall find—

First. At the latitude of 26°, between the coasts of Florida and the Bahamas, $L = 90$ kilometers, $V = 3$ to 4 nautical miles per hour; whence results a difference of level of from $1^m.00$ to $1^m.20$.

Second. At the latitude of 33°, between Cape Henlopen, near Charleston, and the Bermudas, $L = 230$ kilometers, $V = 2\frac{1}{2}$ nautical miles hourly; whence results a difference of level of 2.40 meters.

Third. At the latitude of 42° south of the Banks of Newfoundland, near the point where the current turns toward the east, $L = 470$ kilometers, $V = 1.5$ nautical miles hourly; whence we calculate the difference of level to be 3.60 meters.

These figures are probably a little too large; the velocity of the current grows feebler on its borders, and the inclination of the surface of the sea experiences a corresponding reduction. But after all corrections, these data remain important, and we are forced to admit that the surface of the sea, even in an ocean as open as the Atlantic, is not rigorously horizontal; that over very extended regions it presents inclinations that can amount to many seconds, and a level differing from the mean level of the sea by several meters.

We know that the operations recently conducted for a general leveling of France have indicated differences between the mean levels of the sea in different parts of the Mediterranean and the Atlantic. It is possible that this singular result ought not to be attributed simply to the complexity of the calculations and the observations, but that it may be the expression of a general fact, and that this fact is explained in part by the general oceanic currents which prevail around the coast.

(10) *Supplementary Note.*

My memoir was addressed to the Academy of Sciences of Paris in the latter part of 1869. Toward the end of the following year, we received a copy of the "Atlas of Storms of the Norwegian Meteorological Institute" that Mr. Mohn, director of this institute, has done us the honor of presenting to us, and where we find the following lines on page 11:

"The force of the wind depends on the magnitude of the variation in the pressure of the air experienced from place to place at the surface of the earth, or on the magnitude of the barometric gradient. The greater the variation of pressure from one place to another, the smaller is the gradient and the stronger is the wind.

"This will be seen upon any one of the charts of this atlas. The

more the isobars are crowded together, the more numerous are the pilings of the wind-arrows. In an earlier initial memoir, entitled 'On the Thunder-Storms of Norway in 1868,' I have attempted a determination of the numerical relation between the magnitude of the gradient and the force of the wind, with the following results:

"Gradient.....	20	30	40	50	60	70	80	90	100	kilometers.
"Force of wind.....	4.9	3.9	3.1	2.3	1.8	2.0	1.5	1.8	1.4	on a scale of 6.

"By a graphic interpolation, we deduce from these numbers the degrees of force of wind on the scale employed and the corresponding barometric gradients, as is shown in the following table. The approximate velocity of the wind, expressed in kilometers, per hour, which corresponds to the figures of the scale of force, are also added.

Force of wind.	Hourly velocity of wind.	Barometric gradient.
6. Violent	Over 100 kilometers.	Less than 17 kilometers.
5. Très-fort	70—100	17—23
4. Fort	40—70	23—34
3. Assez fort	25—40	34—50
2. Modéré	14—25	50—100
1. Faible	4—14	Above 100.

"The force of the wind depends so strongly upon local causes that a table like this can have only a general value. We can deduce an inverse ratio between the gradient and the wind-velocity, such that their product is equal to 1460 (Barometric gradient × wind-velocity = 1460). On the sea, the force of the wind will be for the same barometric gradient much greater than in the interior country, where the wind finds far more impediments to its movement over the surface of the earth."

We see that Mohn, in a work independent of ours and probably anterior thereto, has recognized the law of inverse ratio between the velocity of the wind and the distance of the isobars.

Let us compare the numbers resulting from his observations with those that our theoretical formula gives. Mohn measures the velocity of the wind in kilometers per hour; we have taken for the unit the meter and the second. In order to pass from these latter units to the first, the coefficient $\frac{60 \times 60}{1000} = 3.60$ is to be used.

The barometric gradient is defined by Mohn, page 15, as "the number of kilometers that it is necessary to go in the direction of the gradient in order that the pressure of the air may diminish by one millimeter." Our units for δ are a degree of the meridian, or 111 kilometers, and a barometric variation equal to five kilometers. Consequently, the value of the barometric gradient is $\frac{111}{5}\delta$, and its product by the velocity of the wind, $3.60\ V$, in our system of units, will have the value

$$\frac{111}{5}\delta \times 3.60\ V = 80\,V\delta.$$

Our table of corresponding theoretical values of V and δ gives for the latitude of Christiania, or 60° north, the constant product $V\delta = 37.5$, whence $80\,V\delta = 3000$. Mr. Mohn gives as the result of observations on the force of the wind in Norway the mean product $80\,V\delta = 1460$; that is to say, very nearly one-half of our theoretical result. It is easy to recognize the reason of the apparent discordance of these two results. Mohn, in the passage that we have cited, says that "upon the sea the force of the wind will be, for the same gradient, far greater than in the interior of the country."

It is, on the other hand, certain, according to all the observations made both on mountains and in balloons, that the force of the wind increases considerably as we ascend in the atmosphere. And these facts relative to atmospheric currents conform entirely to that which has been established for liquid currents: the velocity at the base or near the borders is notably feebler than the mean velocity of the current.

There is, then, no reason for surprise that the velocities observed by Mohn at the surface of the earth are feebler than the velocities deduced from our theoretical formula, which should give us the mean velocities of the atmospheric currents. The figures that he cites show that, in order to pass from the latter to the former or from the theoretical to the observed velocities, it is necessary to apply a coefficient of reduction, which is 0.40 for the smaller velocities, and which, increasing in proportion as the velocity increases, can become 0.60 for the very greatest velocities.

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